AN EMPIRICAL APPLICATION OF DURABLE RESOURCE THEORY IN THE INVESTMENT/ DISINVESTMENT OF FARM MACHINERY

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AN EMPIRICAL APPLICATION OF DURABLE RESOURCE THEORY IN THE INVESTMENT/ DISINVESTMENT OF FARM MACHINERY

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PREFACE

This study empirically applies durable resource theory in the investment/disinvestment of farm machinery on a hypothetical farm in Northcentral Oklahoma. A key aspect of the durable replacement model used is the recognition of all cost and returns attributable to the durable. The effects of forecasted returns, repair costs, salvage values, farm size, tax considerations, and uncertainty on the optimal economic investment/disinvestment decision are examined.

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Most of all, special recognition is extended to my future wife, Alice, and my parents, Harold and Velda King, for their help and encouragement, which made this study possible.

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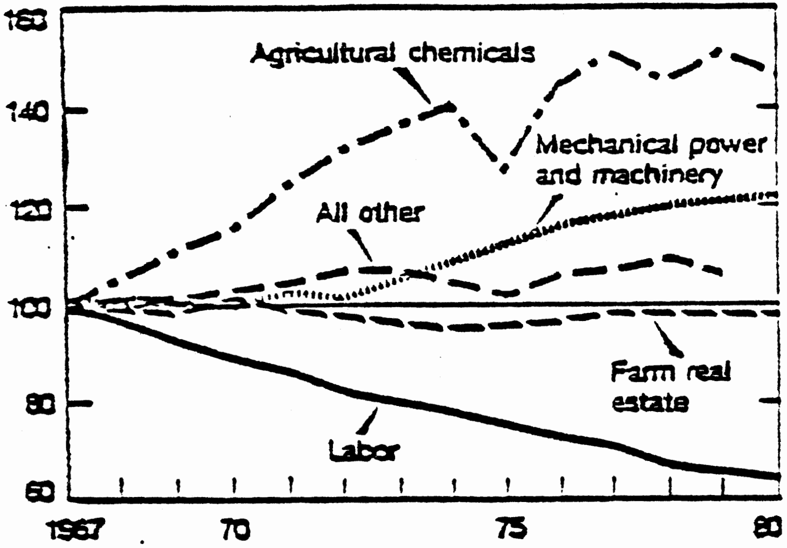
CHAPTER I

INTRODUCTION

The purchase of a tractor and complements is a major investment for farmers. A farmer must make the decision at the appropriate time to disinvest in one durable resource and reinvest in another. The magnitude of a durable's value in use and the optimal replacement date is affected by such factors as the amount the durable is used during each production period, the price of the product produced, the cost of inputs, cost of maintenance, and the number of years of expected use (Baquet, 1980).

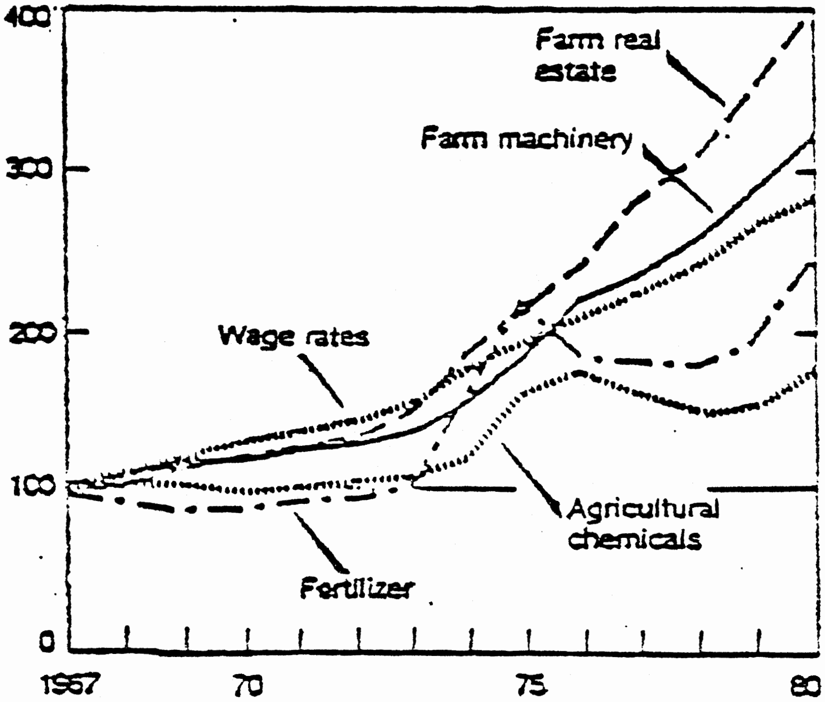
The intent of this study is to determine the effect of these factors on the optimal investment/disinvestment decision. Figures 1 and 2 illustrate the trends in use and prices of selected farm inputs. Farm machinery prices have increased at a faster rate than all other inputs excluding farm real estate. The use of machinery has also increased during this time period, with machinery and chemicals having the largest increases, and use of labor continuing its long-run decline. The number of tractors in the United States has actually only increased 30 percent since 1950; however, during this time period tractor horsepower increased 150 percent (Schertz, 1979).

Oklahoma farmers have been subject to large fluctuations in those variables which affect the durable investment/disinvestment decision. Farm income, which is a function of output prices, yields, and input



Source: U. S. Department of Agriculture (1980b).

Figure 1. Trend in Use of Selected Farm Inputs



Source: U. S. Department of Agriculture (1980b).

Figure 2. Trend in Prices of Selected Farm Inputs

costs, is shown in Figure 3. During the past ten years net farm income in Oklahoma has ranged from a high of 730 million in 1973 to a low of 118 million in 1977.

The Problem

Past studies concerning the economic life of a durable resource and the investment/disinvestment decision assumed a constant usage rate (stock concept) of the durable (Smith, 1957; Yotopoulas, 1967; Perrin, 1972). This was assumed either because of availability of data or the inability to deal with uncertainties that arise when using a flow concept.

Idachaba (1972) and Baquet (1978) explicitly recognized the need for variable usage rates in durable resource investment/disinvestment decisions in U.S. agriculture. Robision (1980) recently detailed all costs which should be considered when taking into consideration variable usage and incorporated them into a theoretical investment/disinvestment resource model. Empirical research that tests the workability and makes use of the theoretical concepts developed by Robison is now needed to further the development of durable resource theory and broaden its applications.

The empirical testing of durable investment/disinvestment concepts and procedures will contribute to the development and understanding of durable resource theory. Farmers in Oklahoma will benefit from a study of this nature by an increased knowledge of all cost associated with the ownership of durables and the effects of various parameters on the investment/disinvestment decision. This increased knowledge will lead to more informed, logical durable resource replacement decisions.

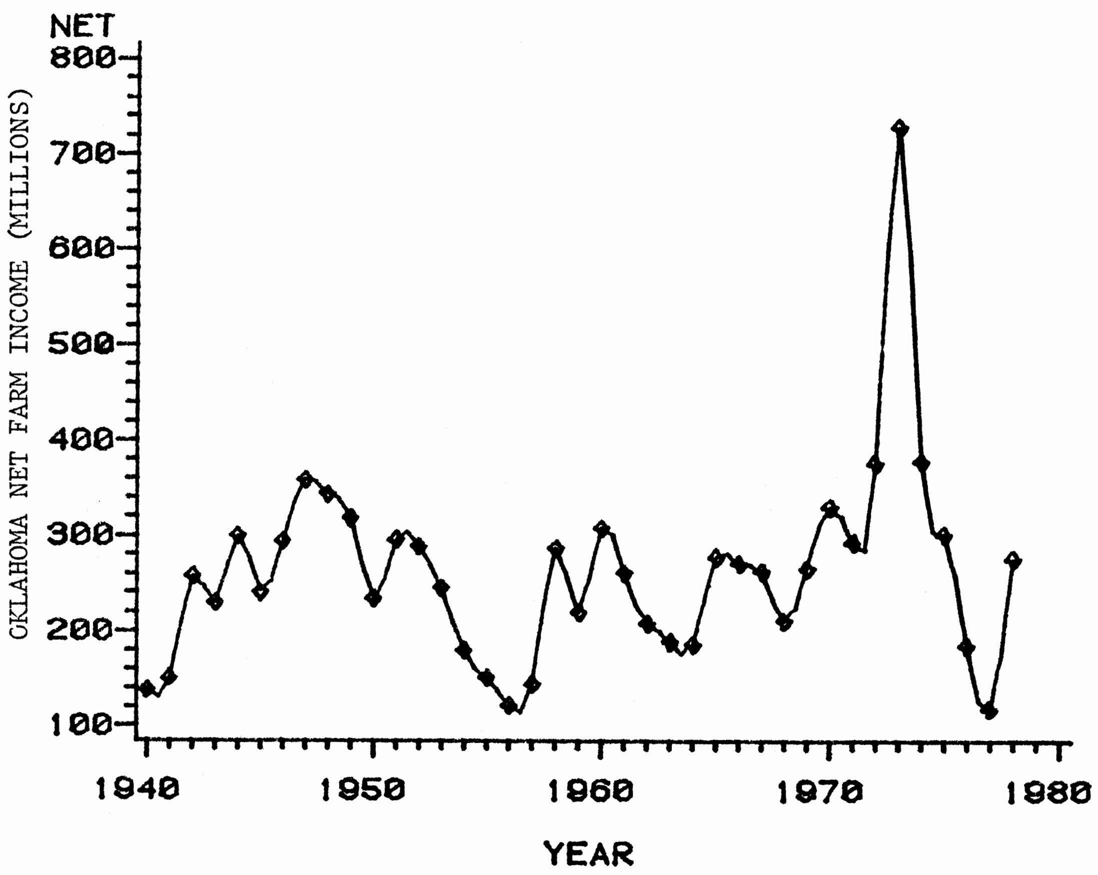


Figure 3. Oklahoma Net Farm Income

Objectives and Procedures

The main objective of this study is to empirically test the durable investment/disinvestment model developed by Robison (1980). Specifically, its usefulness to Oklahoma farmers in making investment/disinvestment decisions for farm machinery will be examined. The procedures used involve projecting net returns to machinery for a hypothetical farm in Northcentral Oklahoma and applying the model to arrive at an optimal investment/disinvestment decision. Other objectives and procedures are:

1. To project returns to machinery for a hypothetical farm in Northcental Oklahoma for the period 1981 to 1995. Forecasting techniques will be used to project future variable costs, machinery costs, crop yields, and crop prices.

2. To incorporate the new tax regulations from the 1981 Economic Recovery Tax Act into the investment/disinvestment model. Procedures involve incorporating taxes, tax investment credits, and tax deductions into the estimated net returns to machinery.

3. To determine the effects of changes in various parameters and economic conditions, the model will be used to conduct sensitivity tests with regard to the various parameters which reflect the economic conditions faced by the firm. Forecasting techniques and assumptions of parameters will be used in developing a base solution. Key variables such as expected returns, machinery repair costs, salvage values, and machinery tax costs will then be varied to examine the changes which occur in the investment/disinvestment decision in comparison to the base solution.

4. To address the issue of uncertainty in durable resource investment/disinvestment. Since future net returns to machinery, salvage values, repair costs, and other variables which affect the investment/disinvestment model are not known with perfect knowledge, several simulations based on probabilities, distribution intervals, and random occurrences will be presented. Several replacement criteria will be tested in this section due to the inconsistency of the analytic model in determining the optimal replacement period with stochastic returns to machinery.

Organization of Remaining Chapters

The organization of the remaining chapters of this study is as follows:

Chapter II reviews the literature used in this study concerning durable resource replacement. The first section presents economic resource theory as presented by Leftwich (1979). Perfect competition is assumed in the buying and selling of resources. The second section examines fixed asset theory. The third section presents analytic frameworks for solving durable investment/disinvestment problems as developed by Faris (1961), Baquet (1980), and Robison (1980). The chapter concludes with an investment/disinvestment durable resource model by Robsion.

Chapter III specifies the assumptions and procedures used in the development of the replacement model. The first section outlines the linear programming constraints and procedures used for forecasting gross returns to machinery. The second section explains repair and maintenance cost calculations. Following this is a review of the

Economic Recovery Tax Act of 1981 as it pertains to the durable investment/disinvestment decision. The chapter concludes with an explanation of the assumptions made in estimating returns to machinery to be applied in the durable replacement model.

Chapter IV applies the procedures and assumptions outlined in previous chapters and determines an optimal replacement period. From this initial application, gross returns, repair costs, salvage values, and taxes are independently varied in order to determine the effect each of these variables has on the optimal replacement decision.

Chapter V incorporates uncertainty and random returns into the model. Probabilities are assigned to gross returns, salvage values, and repair costs. 100 simulations are them estimated by use of a random number generator and the assigned probabilities. Several replacement criteria are analyzed in determining the optimal replacement decision with variable returns to machinery.

Chapter VI summarizes the procedures used in the development of the model, the conclusions reached, and suggests further research needs in the empirical study of durable resource replacement.

CHAPTER II

REVIEW OF DURABLE RESOURCE THEORY

The following chapter is a review of durable resource theory relating to this study. The first section reviews economic theory concerning the valuation of resources as presented by Leftwich (1979). A brief examination of resource employment and pricing at the firm and the market level will be presented with the aid of graphs. This section relates how the investment and production decisions made by other firms in the industry affect the market demand faced by an individual firm.

The second section critiques fixed asset theory. Fixed asset theory as developed by Johnson (1971) and others is based on the divergence between the acquisition price and the salvage price of a durable resource. Fixed asset theory contributed greatly to the development of durable resource study by recognizing the importance to profit maximizing firms of disinvestment in durable assets in an optimal manner.

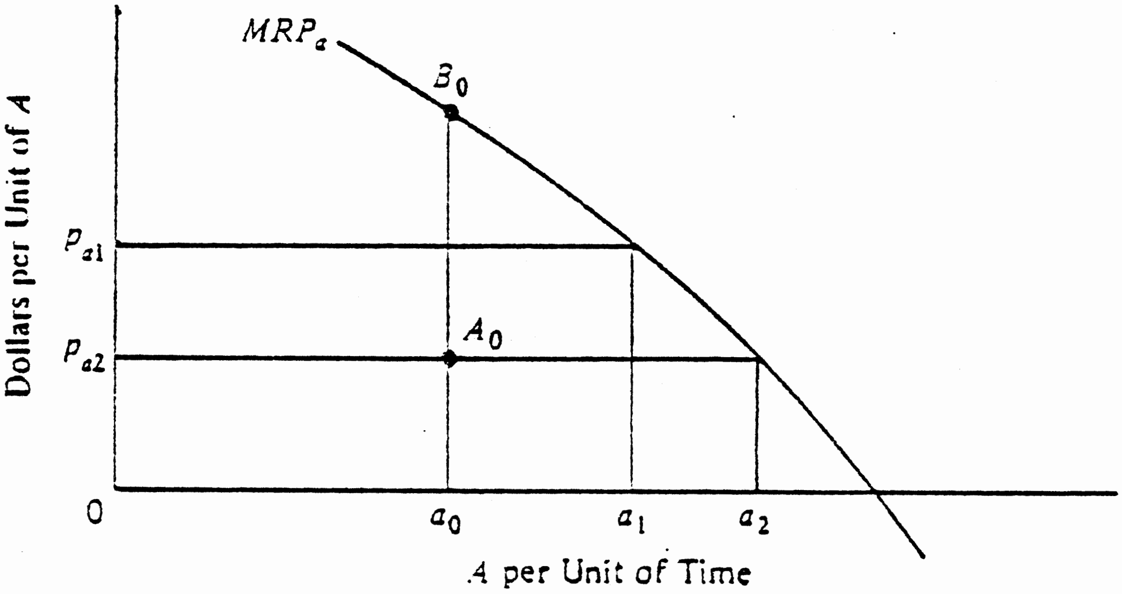
In the third section an analytic framework is developed for solving durable investment problems. A durable replacement model by Faris (1960) is illustrated. Secondly a production process which allows for varying rates of extraction of services developed by Baquet (1980) is presented. In the third part all costs of ownership associated with a durable are outlined in detail. This section concludes with a presentation of an investment/disinvestment durable resource model developed by Robison (1980).

Pricing and Employment of a Given Resource

The following explanation applies to the pricing and employment of variable resources. Perfect competition is assumed in both the buying and selling of resources.

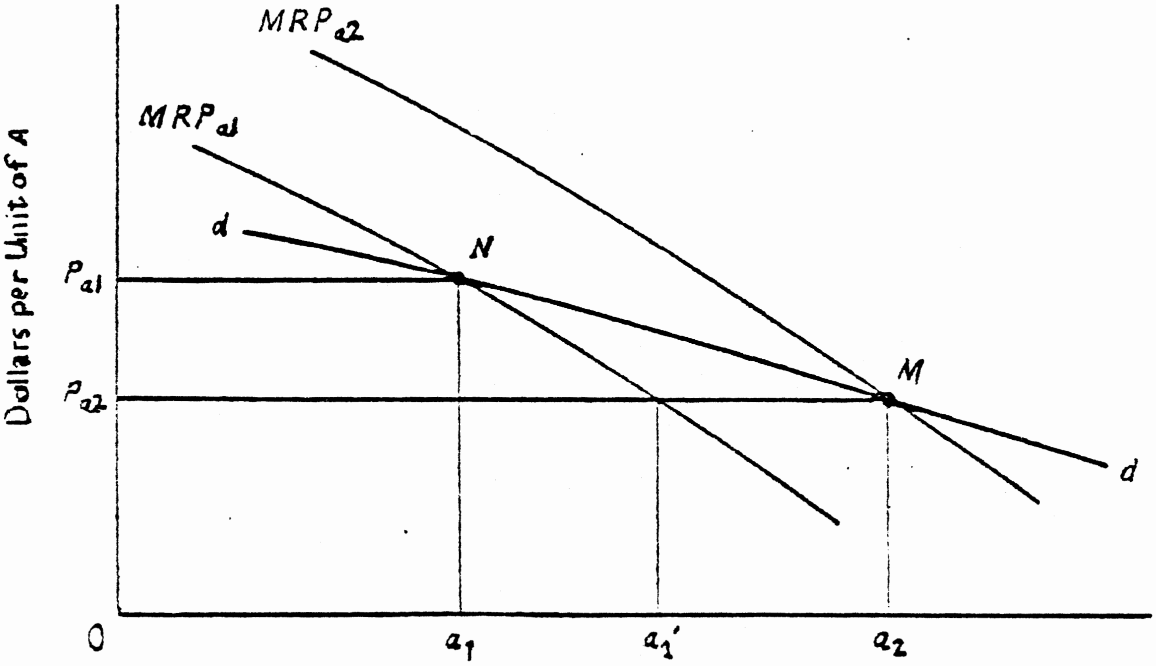
The demand curve for a variable resource shows the different quantities of the resource taken at various prices. Figure 4 illustrates the concept that should be used by profit maximizing firms in perfectly competitive markets. Marginal revenue product is the change in a firm's total receipts when it changes the employment level of some resource A. It is computed by multiplying the marginal physical product of A times the marginal revenue of product X. The marginal value product curve is downward sloping because in Stage II for resource A marginal physical product of A declines as larger amounts of A are applied. The profit maximizing level of employment of resource A by a firm is that level at which marginal revenue product of resource A equals the price of the resource. If resource A is the only variable resource employed, the marginal revenue product curve is the firm's demand schedule for resource A.

When a firm uses more than one variable resource, its demand curve is no longer the marginal revenue product of the resource. This is shown in Figure 5. When several variable resources are used by the firm, a change in the price of one resource, holding others constant, will change the quantities used of other resources and these changes in turn will affect the use of the one resource.



Source: Richard H. Leftwich (1979).

Figure 4. Marginal Revenue Product Curve

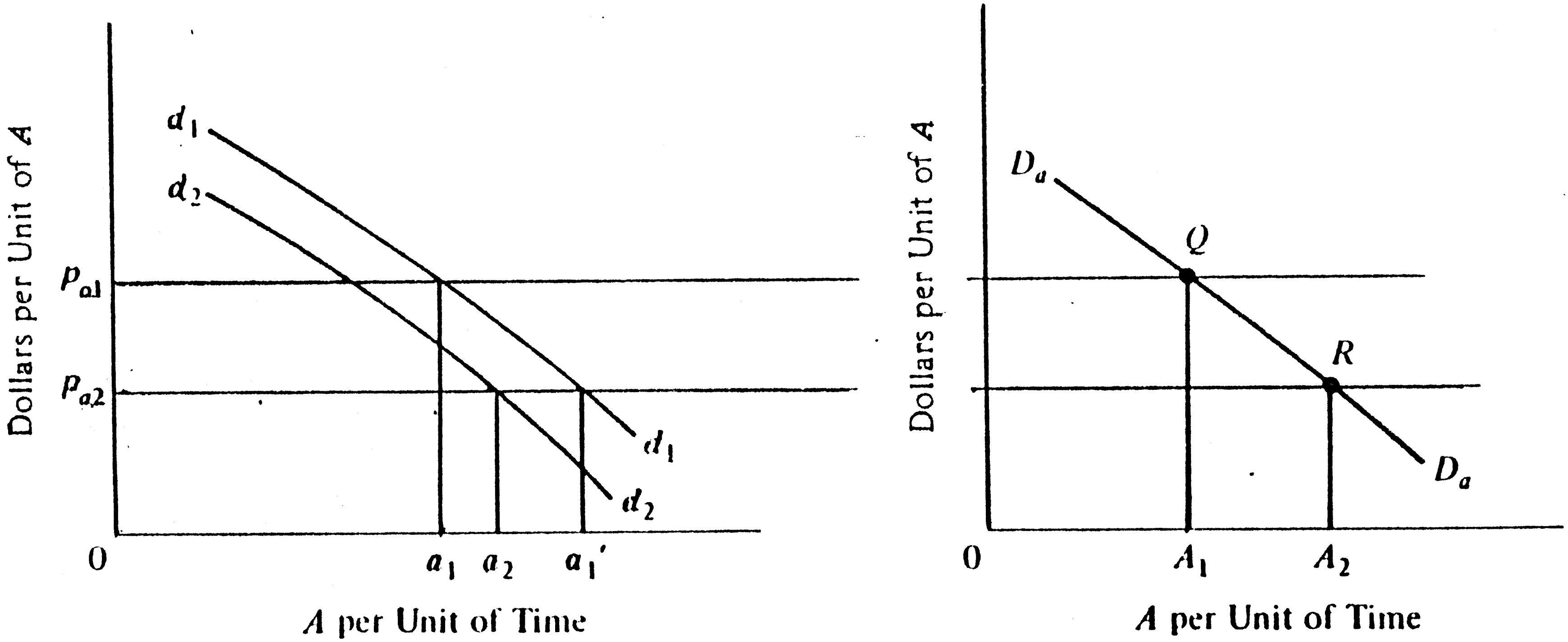


Source: Richard H. Leftwich (1979).

Figure 5. The Firm's Demand Curve for One of Several Variable Resources

Referring to Figure 5, given A is the only variable resource, the profit maximizing firm will utilize quantity a_1 at a price P_{a1}. If the price of a falls to Pa_2, firms would tend to move to a_1'. However, this increase in the use of resource A will increase the use of complement resources and decrease the use of substitute resources. These changes in the use of other resources shift the use of resource A to the right. Point M, where MVP = Pa_2 is the new profit maximizing level at price Pa_2. Each change in the use of other variable resources will result in a different marginal value product curve for resource A. Price shifts as the one shown will establish a firm demand curve for resource A such as dd.

Figure 6 illustrates the market demand for a resource. A summation of individual firm's demand curves for resource a is incorrect, for although one firm in a perfectly competitive market cannot alter price, many firms acting simultaneously will affect the price of output. Given demand curve d_1d_1 and price pa_1 the firm will demand a_1 and the market quantity will be A_1. If the price of A falls to Pa_2, each firm will increase the use of A and expand output. However as all firms expand output, industry output increases and market price of products falls. With the price of products falling, the firm's demand curve for resource A shifts to the left. Thus the firm emplys quantity a_2 of resource A at price Pa_2, instead of quantity a_1'. With each firm making similar adjustments in order to achieve a least-cost combination of resources, a point such as R can be determined for the market demand curve. Other points can be determined in this manner so that market demand curves for resource A such as DaDa can be determined.



Source: Richard H. Leftwich (1979).

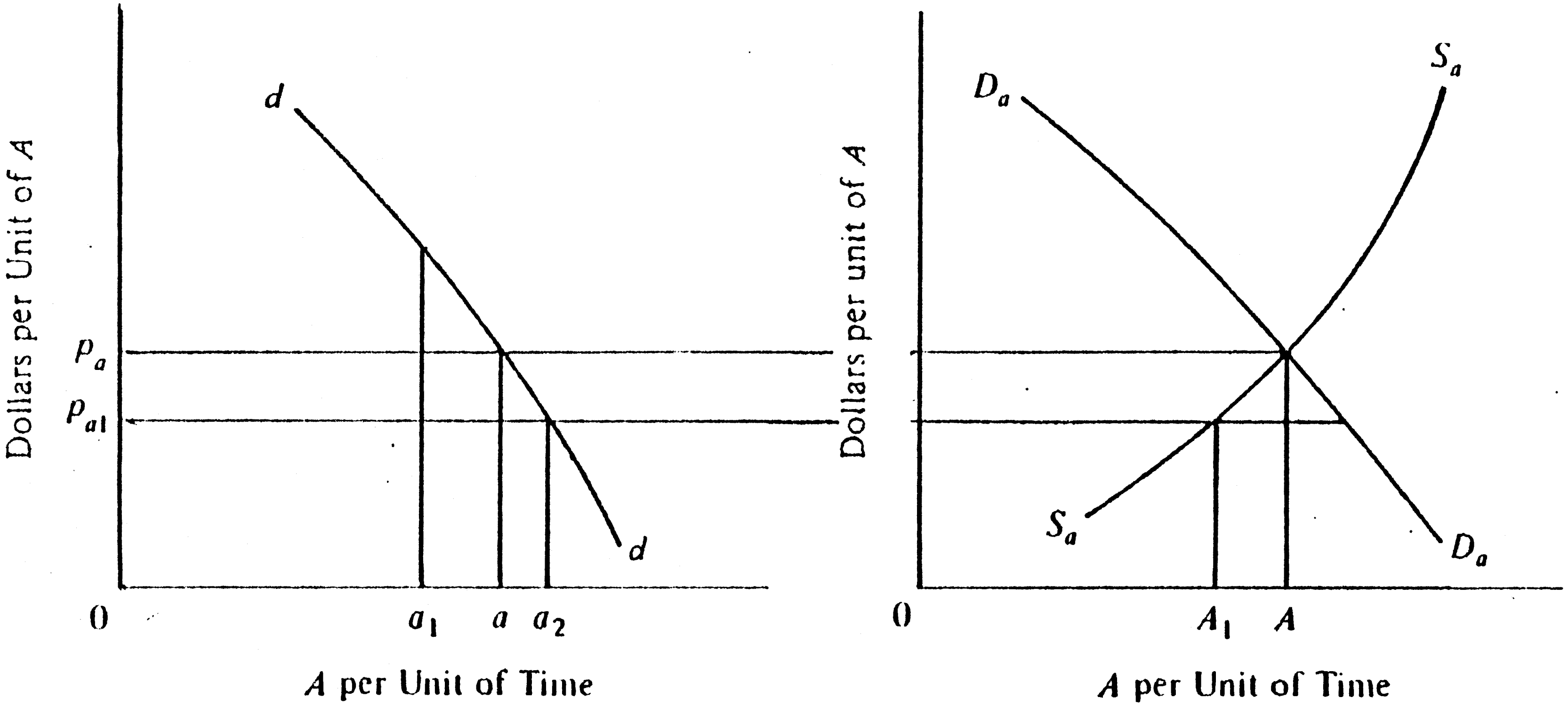
Figure 6. The Market Demand for a Resource

Figure 7 illustrates how prices for resource A are determined. The market supply for resource A shows the different quantities per unit of time of resource A sellers will offer at different prices and is generally upward sloping to the right. Market demand DaDa shows the different quantities per unit of time of resource A buyers will demand at different prices. Equilibrium price is at the intersection of supply and demand with a price Pa and quantity A. At a higher price, supply of resource A will be greater than demand, and price will be driven down. At a price below Pa, resource demand is greater than resource supply, and prices will be driven up. At a price Pa, the individual firm can get as much of resource A as it wants. A single firm cannot affect price Pa, thus the horizontal line at the equilibrium price is the resource supply curve facing the firm. Assuming at price Pa dd is the demand curve for the firm, the firm will utilize resource quantity a. At this level, marginal revenue product of resource a = Pa for the firm.

Economic Rent

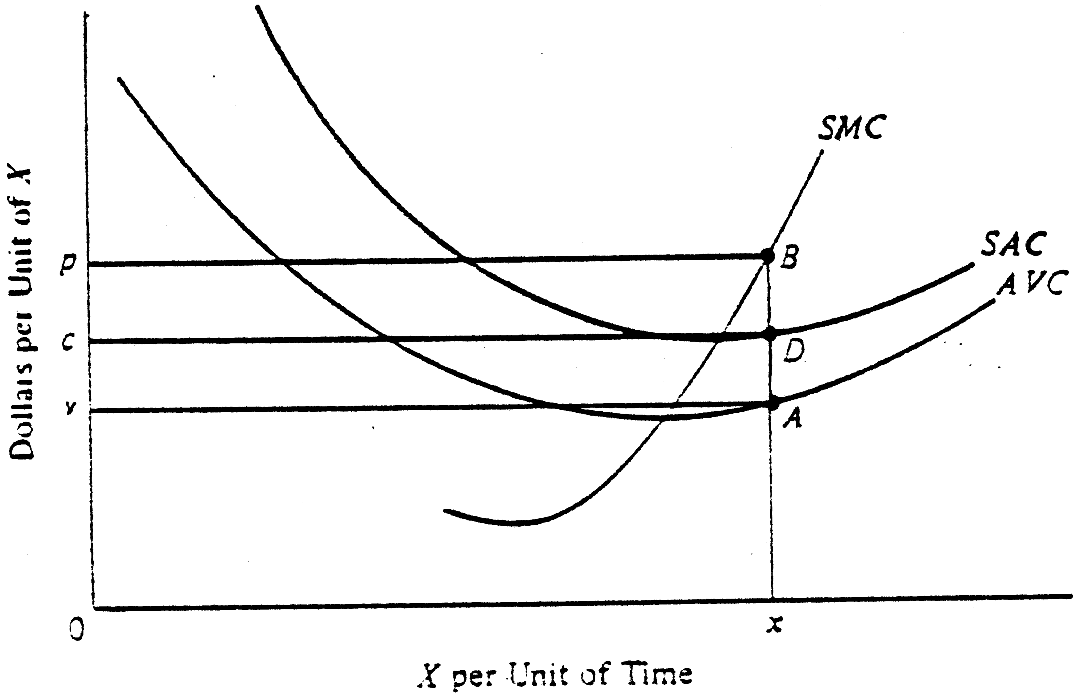
In the short run, some resources are fixed to the firm. Since these fixed resources are not free to move to other employments, the preceding resource theory does not apply. Fixed resources are paid whatever is left after variable resources are paid what is necessary to keep them employed by a particular firm. The amount left for fixed resources is called economic rent.

Figure 8 illustrates this concept. With a price p the firm will produce output x. Total cost of the variable resources if OvAx. This is the outlay necessary if the firm is to hold its variable



Source: Richard H. Leftwich (1979).

Figure 7. Determination of Market Price, Market Level of Employment, and Firm Level of Employment of a Resource



Source: Richard H. Leftwich (1979).

Figure 8. Economic Rent

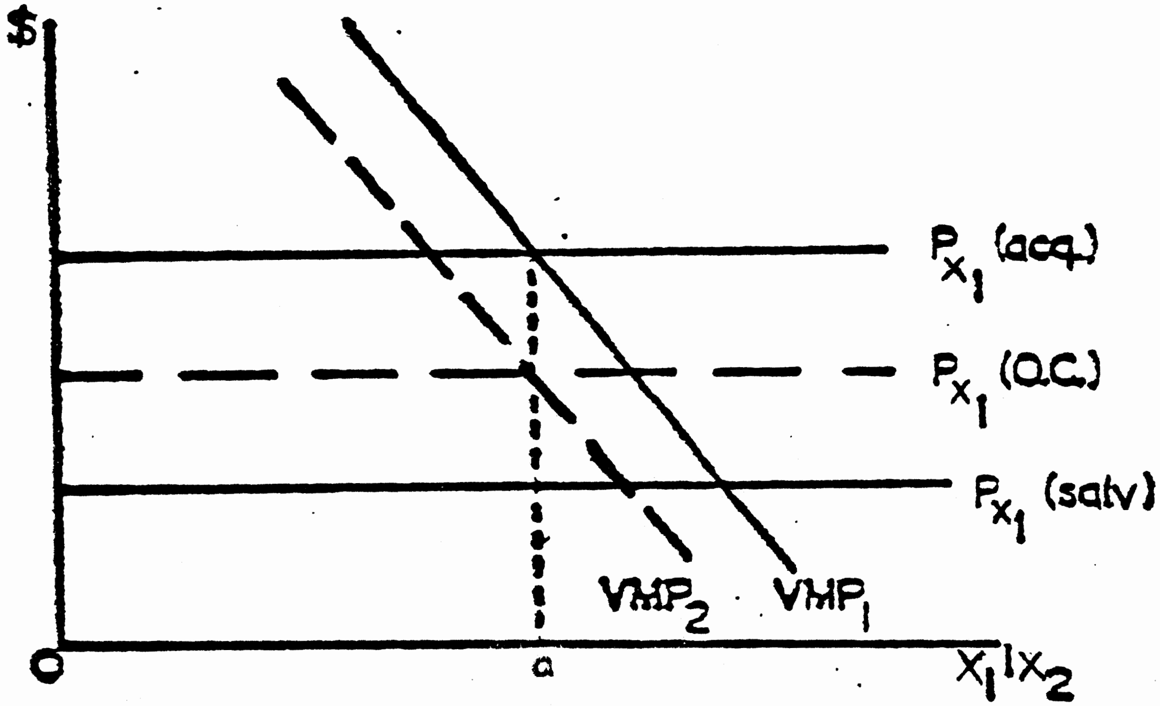
resources. At any outlay less than this, the variable resources would go to alternative uses. The economic rent, or returns above total variable cost left to cover fixed cost, is vpBA. Rents may be greater, equal, or less than the firm's fixed cost. When rent is greater than fixed cost the firm is earning pure profits; when equal, the firm is making normal profits, and when less than fixed cost the firm is incurring a loss.

Fixed Asset Theory

A profit-maximizing firm selling in a competitive market will apply a resource in the production of a product X until the value of the marginal product (VMP) equals marginal factor cost which is the price of resource a in a competitve market. Fixed asset theory as developed by Johnson(1971) and others is based on the divergence between the acquisition price and the salvage price of a resource.

Figure 9 illustrates this concept for a single variable resource. The within-firm opportunity cost Px_1 (O.C.) is assumed to exceed the salvage value Px_1 (salv.). With initial condition VMP = Px_1 (acq.) the firm acquires amount a of resource x. If the product price falls to VMP_2, fixed asset theory states resource x is fixed because VMP at quantity Oa is less than the price of acquisition and greater than price of salvage. Thus, it is concluded that resources are 'trapped' in production since Px (acq.) is greater than VMP which is greater than Px (salv.) and no adjustment in resource use should be undertaken.

Johnson (1981) arques that the conclusion of low resource returns due to resources being trapped in production as explained by fixed asset theory is incorrect due to the use of acquisition cost as the



Source: Marc A. Johnson and E.C. Pasour, Jr. (1981).

Figure 9. Fixed Asset Theory

opportunity cost of a resource. Opportunity cost is the value of a resource in the best alternative use. Once a resource is purchased, the price of acquisition is a sunk cost and is no longer relevant in the decision of resource use. For a single-product firm, the opportunity cost of an owned resource is the market salvage value. For a multiple product firm, the opportunity cost of an owned resource is the value in the best alternative use. Thus, resources are attracted to the use for which they have the greatest value and rates of return in use are competitive with current alternatives.

Replacement Model Based on Net Returns

Bu using actual or estimated data, cost and revenue functions may be estimated. Subtracting cost from gross returns of the firm results in the information upon which total, average, and marginal net revenue curves are computed. It is extremely important to keep in mind that <u>net</u> revenue curves are used in the replacement model bu Faris (1960).

Total, average, and marginal net revenue curves are shown in Figure 10. The important concept illustrated in this model is that maximizing average net revenue over time for the firm is different than maximizing net revenue for a single time period. Maximizing net revenue from a nondurable resource occurs at point b on Figure 10, in which total net revenue (TNR) is at a maximum and marginal net revenue (MNR) equals zero. Maximum net revenue from a durable resource occurs at point a. Geometrically point a is found at the point in which a straight ray from the origin is just tangent to the total net revenue curve. At this point average net revenue over

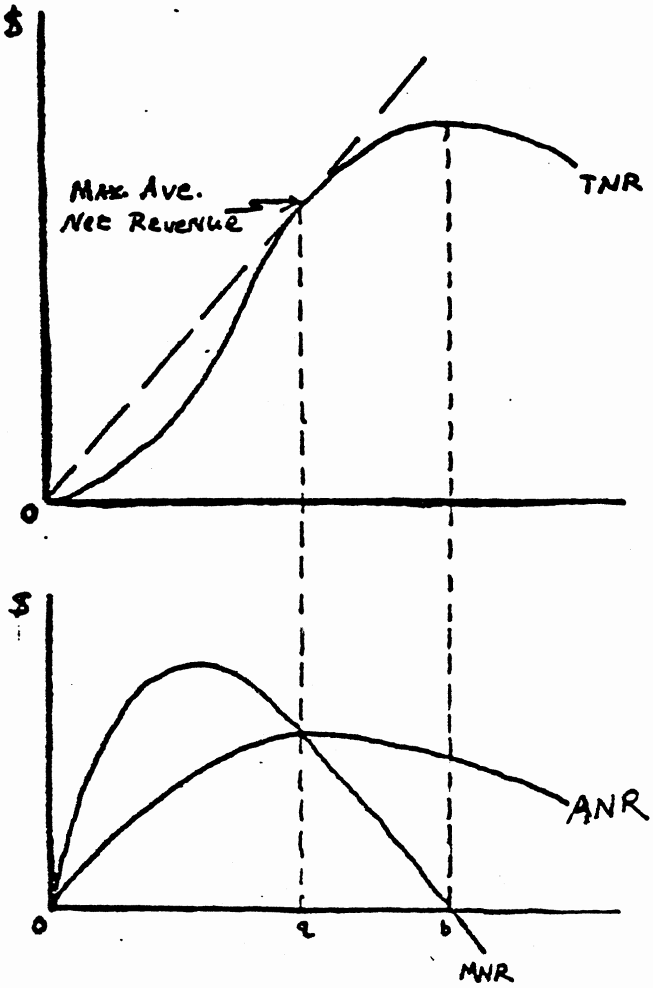


Figure 10. Maximization of Average Net Revenue

time is at a maximum, and average net revenue equals marginal net revenue.

The preceding discussion assumes a short production period. By introducing a long production period net revenues must be discounted in order to reflect time preferences. Time preference takes into account opportunity cost by assuming that a sum of money received or paid at the present time is worth more than the same sum of money at some point in the future. To reflect time preference, Faris (1960) restates the principle of optimum replacement for enterprises with a long production period with revenues being realized throughout the life of the asset as:

> The optimum time to replace is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenue from the following enterprise (p.766).

If, as Robison (1980) does in a following section, it is assumed that the current and future durables have identical net revenues, the marginal net revenue may be compared to the amortized present value of the net revenue of the present durable.

A Theory of Production, Investment, and Disinvestment

Past studies concerning the economic life of a durable resource and the investment/disinvestment decision have assumed a constant usage rate (stock concept) of the durable (Yotopoulos, 1957; Perrin, 1967; and Smith, 1972). This was assumed either because of availability of data or the inability to deal with uncertainties that arise when using a flow concept. In the theoretical model developed by Baquet (1980) below, both durable assets and the flow of services from the durable are inputs in the production process. Varying extraction rates are allowed for in determining the optimal amount of services to be extracted from the durable in each production period.

The production process in this model is specified as vertically integrated. The determination of the flow of services from durables is specified at one level. This service flow is then computed into the production function to determine output. The expected future use of the durables determines the investment/disinvestment decision. A diagrammatic representation of this process for a production process using one durable is presented in Figure 11.

Mathematically, the physical production process in Figure 11 is illustrated in the following three equations:

$$Y_t = f(X_{1t}, Z_t) \tag{1}$$

$$Z_t = g(X_{2t}, D_t) \tag{2}$$

$$T_D = h(Z_1, \ldots, Z_t, \ldots, Z_{TH}, X_{31}, \ldots, X_{3t}, \ldots, X_{3TH} \tag{3}$$

where

t = quantity of nondurable inputs X_1 used in production of Y_t in time period t,

X_{2t} = quantity of nondurable inputs X_2 used in combination with durable D in time period t,

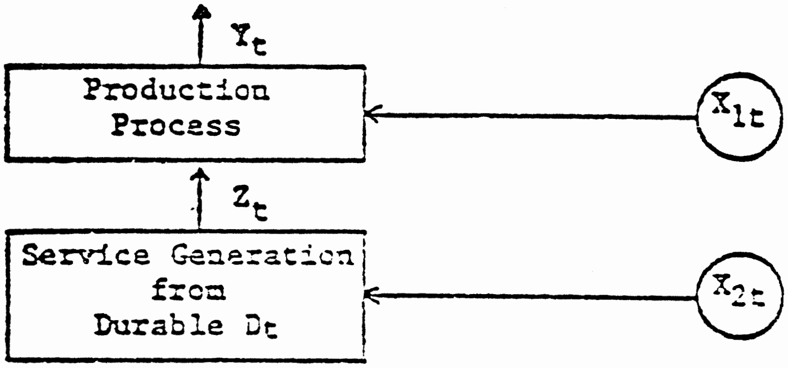
Z_t = quantity of ervices generated from D_t used in production of Y in time period t,

T_D = physical life of durable,

X_{3t} = aggregated maintenance variable in time period t,

T_H = planning horizon for the firm.

Equation (1) is a standard representation of a production process with flow variables as inputs. Equation (2) is a production



Source: Alan E. Baquet (1980).

Figure 11. Two Tiered Vertically Integrated Production Process

relationship which indicates that service flows from a durable asset are generated or produced according to the function G(.) by using one nondurable input (a flow variable) with a given stock of the durable asset. Thus both stocks and flows are needed at this level of integration. Equation (3) relates the physical life of the durable to the services extracted and the maintenance performed during each year of its life.

Specification of the production process in the above manner allows the rate of use of durable assets to be variable. It allows for the investment/disinvestment in durables to be determined simultaneously with the production activities associated with the durable.

Objective Function

The objective function developed by Baquet (1980) assumes that the firm operates in each time period to maximize current profits plus the change in the net present value of the durable asset. This objective functions is defined as follows;

$$G_t = P_{yt}Y_t - P_{x1t}X_{1t} - P_{x2t}X_{3t} - TUC_n(Z_t) - FC_t + a(D_t - D^o{}_t) \tag{4}$$

where

P_{yt} = price received for Y in time period t,

P_{xjt} = price paid for nondurable X_j in time period t, j=1,2,3,

$TUC_n(Z_t)$ = total use cost of extracting services Z_t in time period t,

$FC^o{}_t$ = fixed cost associated with the durable in time period t, (the "o" rotation refers to initial levels),

a = gain in net present value of a unit of the durable.

The total user cost concept of a durable is a critical variable in this objective function and a detailed examination by Robison (1980). is presented in the following section.

Maximizing equation (4) subject to (1) through (3) involves determining the optimal production, service generation, and investment/disinvestment activities. The determination of the investment/disinvestment activities will be presented following the explanation of durable ownership cost. Determining the optimal production and service generation activities involves maximizing the following Lagrangian expression:

$$\begin{aligned} L = {} & P_{yt}Y(X_{1t},Z_t) - P_{x1t}X_{1t} - P_{x2t}X_{2t} - \\ & P_{x3t}X_{3t} - TUC_n(Z_t) - FC - \lambda_{1t}(Y_t - f(X_{1t},Z_t)) - \\ & \lambda_{2t}(Z_t - g(X_{2t}/D_t)) - \lambda_{3t}(T_{dh}(Z_1,\ldots, Z_{Th}, \\ & X_{31},\ldots, X_{3TH})) \end{aligned} \tag{5}$$

Upon taking the required partial derivatives, equating them with zero, and making appropriate substitutions, the following necessary conditions are derived.

$$P_{yt}\frac{\partial Y_t}{\partial X_{1t}} = P_{x1t} \tag{6}$$

$$P_{yt}\frac{\partial Y_t}{\partial Z_t}\frac{\partial Z_t}{\partial X_{2t}} = P_{x2t} + MUC_N(Z_t)\frac{\partial Z_t}{\partial X_{2t}} - \frac{P_{X3t}}{\frac{\partial h}{\partial X_{3t}}}\frac{\partial h}{\partial Z_t}\frac{\partial Z_t}{\partial X_{2t}} \tag{7}$$

$$\left[\frac{MUC_N(Z_t) + \frac{P_{x2t}}{\frac{\partial Z_t}{\partial X_{2t}}} - P_{Yt}\frac{\partial Y_t}{\partial Z_t}}{\frac{\partial h}{\partial Z_t}}\right]\frac{\partial h}{\partial X_{3t}} = P_{x3t} \tag{8}$$

$$P_{yt} \frac{\partial Y_t}{\partial Z_t} = MUC_N(Z_t) + \frac{P_{x2t}}{\frac{\partial Z_t}{\partial X_{2t}}} - \frac{P_{x3t}}{\frac{\partial h}{\partial X_{3t}}} \frac{\partial h}{\partial Z_t} \tag{9}$$

Equation (6) indicates that the optimal quantity of X_{1t} to use is determined by equating the value of its marginal product to its price. Equation (7) states that the optimal quantity of X_{2t} to use involves having the instrumental marginal value product equal to the marginal cost of using X_{2t}. The marginal cost of X_{2t} is respectively the price of X_{2t} plus the marginal user cost of the services generated by using X_{2t} plus the increased maintenance costs which must be incurred as a result of using the durable.

For X_{3t}, equation (8) indicates that the net marginal value of maintenance should be equated to the marginal factor cost of maintenance. The net value of a unit of maintenance is given in the square brackets in equation (8).

Equations (6) through (8) state the marginal conditions for the optimal levels of X_{1t}, X_{2t}, and X_{3t}, respectively. For services from the durable, equation (9) indicates that the value of the marginal product of services should be equated with the marginal cost of acquiring services. This marginal cost is composed of the marginal user cost, the weighted cost of acquiring X_{2t}, and the weighted cost of increased maintenance.

The simultaneous solution of equations (6) through (9) for each t, t=1,..., T_H will yield the optimal production activities for the firm with its initial endowment of D_t. The following section critiques durable ownership cost and presents an investment/disinvestment model developed by Robison (1980).

Durable Ownership Cost

Definition of a Durable

For an arbitrarily defined period, non-durable assets are used up, i.e., do not exist in the same form after a single period. Durable assets are not used up, they exist in nearly the same form for more than one time period. This one characteristic is the only distinguising feature differentiating durable from nondurable resources in this study. The distinction between durables and nondurables based on its existence over an arbitrarily defined time period allows the decision maker himself to determine which assets are durable based on his relevant planning horizon.

If nondurable assets do not have a life beyond a single time period, then their costs are the costs associated with their acquisition and use. If durable assets have a life beyond a single period, then there are costs associated with their acquisition and use plus costs of ownership over time. The following is a summary of all costs which result from the ownership of a durable resource as presented by Robison (1980).

Cost of Owning a Durable Resource

The cost of owning a durable resource can be divided into three categories. These are: (1) those current period cost incurred because of changes in the capacity of the resource to deliver services, either as a result of use or the passage of time - capacity cost; (2) costs that occur as a result of holding an inventory of extractable services over time - inventory cost; and (3) those future period costs (benefits) resulting from current-period use decisions - indirect capacity costs. Each of these costs are examined below.

Capacity Costs Associated with Durable Assets

There are three categories of capacity cost associated with a durable: (1) costs that occur as a result of use, called direct user costs; (2) those that occur as a result of time, called capacity time costs; and (3) those that occur as a result of maintenance, called maintenance costs. These costs are examined below.

Direct User and Capacity Time Costs. Direct user cost is the replacement cost of an asset used up. In the case of nondurable assets used up in a single time period, the direct user cost equals its acquisition price. This price, a cost to the firm, is a charge for converting the asset from an input to an output through a production process. There is a similar cost association with using a durable asset in a production process; however, the measurement of the durable's capacity used up is more complicated than measuring the value of nondurable assets because of (a) prices change over time and (b) the quality of the durable may be altered as a result of time, maintenance, and use.

Three measurements help conceptualize the measurement of user and capacity cost. Operating capacity is defined as the potential rate at which services can be extracted from the durable. Rated capacity is defined as the operating capacity which minimizes the average loss in lifetime capacity. Lifetime capacity is defined as the total amount of services available from the durable if services are extracted at the durable's rated capacity. The lifetime capacity depends on (1) operating capacities used to extract services from the durable, (2) conditions under which services are extracted, e.g. weather, (3) maintenance, both scheduled and unscheduled, (4) quality of inputs used in combination with the durable, and (5) time interval over which the services are extracted. The operating capacity used in the current period may also influence the operating capacities available in the future.

The measurement of costs above is physically dependent upon the durable and the services it can deliver. For the development of a model which determines the economic optimal life of the durable it is necessary to value in dollars the cost of using up the durable or altering its capacity to deliver services through time. The acquisition price, if the durable is being purchased, or the salvage price, if the durable is already owned by the firm, reflects the present value of services expected from the durable. As explained in the examination of fixed asset theory, a firm determines a maximum bid price for a durable based on expected services and acquires it if the value determined is higher than the acquisition cost. As services are extracted from the durable, the value in use is continually compared to the market price and the durable is retained by the firm as long as the value in use exceeds the market or salvage price. Thus the change in the durable's salvage price associated with using up the durable reflects the cost, a direct user cost and time capacity cost, incurred by the firm in order to extract services from the durable.

Maintenance Cost. The third capacity cost identified is maintenance cost. Maintenance is a cost that is designed to alter the losses in lifetime capacity associated with time and use. With complete maintenance, it is theoretically possible to extend the life of an asset indefinitely (Baquet, 1980). Because the services derived from maintenance may extend beyond a single time period, maintenance itself may be considered a durable investment.

Inventory Costs. Because a durable has a life beyond a single period, it generates benefits and costs in common with all inventories of assets. Two inventory costs, time depreciation and control costs, are identifed below.

Time depreciation cost is the difference between acquisition and salvage price in the period the durable is acquired and the change in the asset's salvage price in later periods as a result of factors other than changes in capacity discussed in the preceding sections. Time depreciation costs are the result of changes in demand for the durable and/or the output produced from the durable's services. Inflation may also change prices in general and the durable's in particular. Also, the durable's value may change over time because the market in which the durable is traded is not perfect. These external pricing considerations should be entered into the firm's cost considerations by valuing the remaining lifetime capacity of the durable according to its opportunity cost. If the durable is owned by the firm, then it has two alternatives; to keep it or to sell it. If the firm keeps the durable, then one opportunity cost is the change in the salvage price of the durable between periods. This cost is referred to as time depreciation cost.

To hold an asset commits resources to those assets. Thus funds used to purchase resources are not available for investment elsewhere. This opportunity cost is referred to as control cost. If equity funds are involved, the control cost is the foregone earnings on the next best investment opportunity. If borrowed funds are involved, the cost is the interest paid on the loan and the cost associated with a reduced credit reserve.

Indirect Capacity Costs. The final category of cost associated with the ownership of a durable resource is indirect capacity cost. This category includes indirect user costs and replacement opportunity cost.

Indirect user cost is that cost which measures the impact of current decisions to extract services from the durable on future control and time depreciation costs. Since control and time depreciation costs depend on the inventory of lifetime capacity held, decisions to use up capacity in the current period simultaneously affect time depreciation and control costs in the future. Current period decisions may alter the time when the durable is replaced or salvaged. Replacement opportunity costs are the opportunities foregone by failure to replace. An example would be the continued use of a late model tractor. Replacement opportunity cost, for example, could be the fuel savings available from a more efficient tractor.

Benefits from Durable

Identifying both benefits and costs of extracting services from a durable is a necessary step in determining the optimal investment/disinvestment period. Costs of durable ownership have been developed. Expected benefits of durable ownership are the acquisition of services to be used for producing goods of at least equal value to the cost of durable ownership. Another benefit besides the sale of goods produced in some cases may be the appreciation in the price of the durable over time.

Durable Investment/Disinvestment Model

The investment/disinvestment model used in this study is based on the theoretical models and the costs and return definitions specified in previous sections. In applying the model, a 'best guess' as to the durable's economic life is required. From this a multiperiod gain function G is developed which reflects all returns and costs attributable to the durable. This gain function may be represented as:

$$\begin{aligned} G = {} & P_{y1}Y_1(1+r)^{-1} + P_{ys}Y_s(1+r)^{-s} - \\ & ((TD + DUC + CTC) + CC + VC))(1+r)^{-1} - \\ & \ldots\ldots - \\ & ((TD + DUC + CTC) + CC + VC))(1+r)^{-s} \end{aligned} \tag{10}$$

where

P_yY = total returns attributable to the services obtained from the durable to produce Y,

Y = output,

P_y = price per unit of Y,

TD = time depreciation cost which equals the change in salvage value attributable to changes in demand for the durable and/or output produced from the durable's services,

DUC = direct user cost which equals the change in salvage value associated with using up of services generated by the durable,

CTC = control time cost which equals the change in salvage value that occurs as a result of time,

(TD + DUC + CTC)= total change in salvage value which represents time depreciation cost, direct user cost, and control time cost,

CC = control cost which represent the opportunity cost of controlling the asset,

VC = variable cost of production,

r = discount rate.

The gain function developed above represents net returns attributable to the asset for its estimated life. The current period is designated as period 1 and the last period as period s. Net returns in each period are computed by subtracting from gross returns; direct user cost, capacity time cost, time depreciation cost, control cost, and variable cost. The remainder should equal returns resulting only from services generated by the durable. Since the economic life of the durable depends on the economic life of all durables in the future, it is assumed that the returns attributable to future durables are identical to the first.

The optimal economic life of the durable may be found by examining the relationship below;

$$g(s) > r(1-(1+r)^{-s})^{-1}G \tag{11}$$

where

g(s) = net returns attributable to the durable in each period,

r = discount rate,

s = time period,

G = multi-period gain function,

$r(1-(1+r)^{-s})^{-1}G$ = annualized average return.

If $g(s)$ is greater than $r(1-(1+r)^{-s})^{-1}G$ is true, the marginal contribution of the durable in the last period exceeds its annualized average of a replacement with an identical economic performance, so s should be increased. If $g(s)$ is less than $r(1-(1+r)^{-s})^{-1}G$, the last period's net gains reduced the annualized average and a higher annualized average return could be realized by shortening the economic life of the durable.

Only if:

$$g(s) \geqq r(1-(1+r)^{-s})^{-1}G \ \underline{\text{and}}\ g(s+1) < r(1-(1+r)^{-s-1})^{-1} \qquad (12)$$

are true, has the optimal life of the durable been found. If more than one durable is under consideration, the durable with the largest annualized average return should be chosen and acquired if the net present value of G is positive.

CHAPTER III

MODEL SPECIFICATION

The approach used in this study for determining optimal investment/disinvestment of durable resources combines concepts developed by Baquet (1980) and Robison (1980). Baquet defines a production process which has both durable assets and the flow of services from the durables as inputs. Varying extraction rates are allowed for in determining the optimal life of the durable. Robison uses an iterative approach in which the optimal life of the durable is assumed to be known, (choosing s). By comparing the returns in the s-th period g(s) with the annualized average $Gr(L-(1+r)^{-s}$, an optimal life period may be determined. If the last period's returns exceeds the annualized average of the multi-period gain function, the time period of analysis selected was too short and should be increased. If g(s) equals or exceeds $Gr/(1-(1+r)^{-s}$ and g(s+1) is less than $Gr/(1-(1+r)^{-s-1})$, the optimal economic life of the resource has been found.

A systems model with four major components was developed to test Robison's investment/disinvestment model (Figure 12). A linear programming subsystem determines optimal crop production given projected returns less variable cost/acre. After determining machinery usage each year from the linear programming subsystem and Oklahoma State Enterprise Budget guidelines, the second subsystem computes durable asset ownership costs using 1980 American Agricultural Engineer

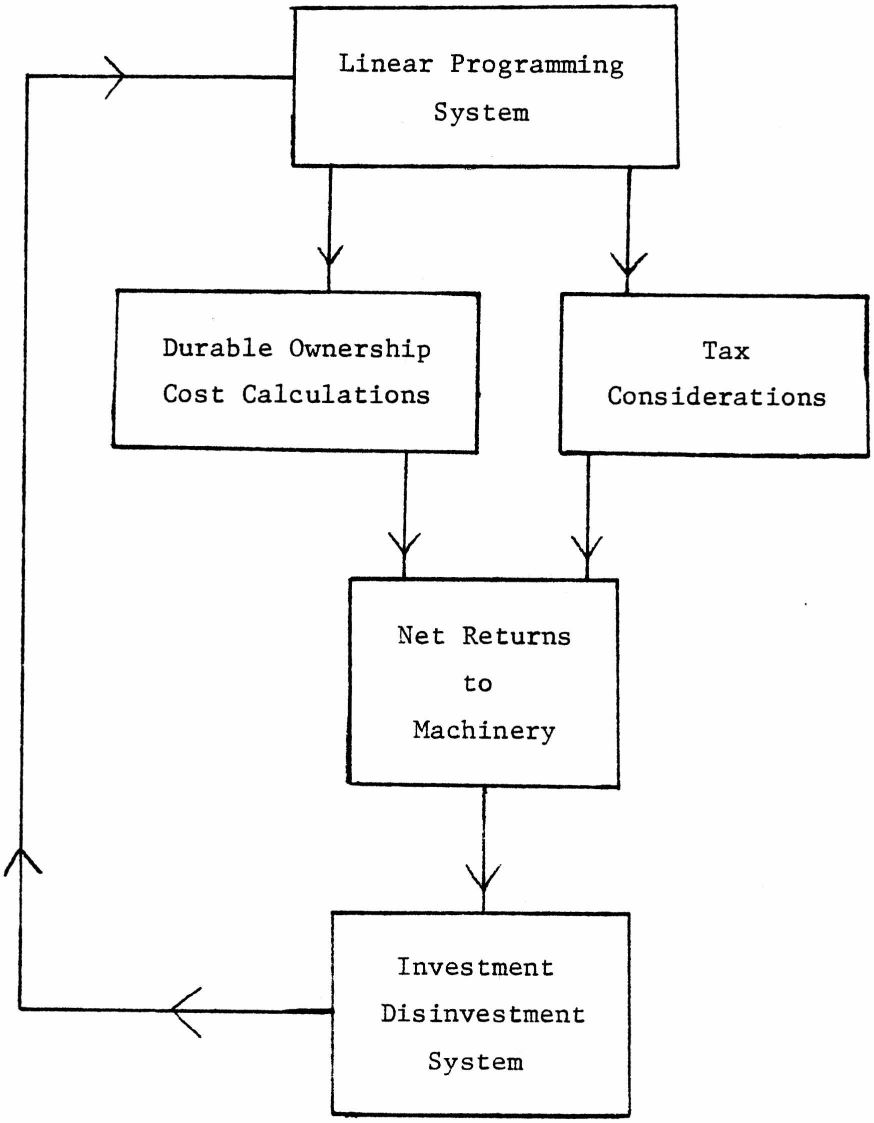


Figure 12. Systems Design of Replacement Model

Yearbook equations and guidelines explained by Robison. The third subsystem separates returns to machinery from returns to other fixed factors of production and estimates the tax consequences of the machinery investment. The fourth subsystem computes the returns to the machinery complement throughout a fifteen year period and determines the optimal economic life of the machinery complment.

Linear Programming Subsystem

Linear programming is a useful procedure for optimizing an objective such as maximizing profits given projected gross returns, variable costs, and constraints. A hypothetical farm consisting of 625 acres of potential cropland in Northcental Oklahoma was the base for testing the investment/disinvestment model in this study. Wheat is the major crop grown in Northcental Oklahoma, accounting for 93 percent of total cropland in 1980. However historical Oklahoma State Enterprise budgets show grain sorghum as a potentially more profitable crop, thus these two crops will be considered in determining the optimal product combination.

Assumptions and Data

Land. The hypothetical farm in Northcentral Oklahoma consists of 625 acres of potential cropland. 250 acres is classified as Class I land and 375 acres as Class II land. Class II land is assumed to produce ten percent less yields for any crop produced in any given year as compared to Class I land.

Labor and Capital. Technical coefficients as to labor hours needed to produce an acre of wheat or grain sorghum are given in Table I. These estimates are taken from Oklahoma State Enterprise budgets for Northcental Oklahoma. 3.3 hours of labor are needed to produce one acre of wheat at a labor cost of $13.20. An acre of grain sorghum requires 2.39 hours at a cost of $9.56. Monthly labor constraints assumed in this study were February, 200 hours, March, 250 hours, April, 250 hours, May 275 hours, June, 350 hours, July, 350 hours, August, 325 hours, September, 275 hours, and October, 270 hours. The enterprise is assumed to be able to meet projected variable cost in each production period.

Gross Returns. Regression models for the base machinery replacement solution were estimated using gross returns as the dependent variable with year and year squared as the independent variables for the purpose of projecting wheat and grain sorghum returns/acre for the period 1982-1995 in Northcental Oklahoma. Equations estimated in the study were selected for use in the base solution on the basis of R^2's, t-values, and standard errors. Chapter IV also examines the effect upon the replacement decision of using other returns and cost forecasting equations.

Seasonal price and yield data for the years 1950-1980 were used in developing the equations. The equations along with R^2 and standard deviations are listed below. T-values are listed in parenthesis below the parameters.

TABLE I

TECHNICAL COEFFICIENTS AND COST OF PRODUCTION PER ACRE FOR ALTERNATIVE ACTIVITIES IN 1982 BASE PERIOD

	MONTH												
ACTIVITY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
Wheat Labor Hours	.0	.34	.0	.0	.0	1.15	.68	.53	.6	.0	.0	.0	3.30
Grain Sorghum Labor Hours	.0	.0	.51	.23	.27	.26	.47	.0	.0	.65	.0	.0	2.39
Wheat Labor $	.0	1.36	.0	.0	.0	4.6	2.72	2.12	.0	2.4	.0	.0	$13.20
Grain Sorghum Labor $	.0	.0	2.04	.92	1.08	1.04	1.88	.0	.0	2.6	.0	.0	$ 9.56

Source: Oklahoma State University Enterprise Budgets (1981).

Dependent variable: Wheat gross returns/acre, Class I land

$$\text{Gross Returns/acre} = \underset{(3.86)}{849.12} - \underset{(-4.1)}{27.7}\ (\text{year}) + \underset{(4.59)}{.2346}\ (\text{year})^2$$

$R^2 = .75$ Standard Deviation = 20.32

Dependent variable: Wheat gross returns/acre, Class II land

$$\text{Gross returns/acre} = \underset{(3.86)}{764.31} - \underset{(-4.1)}{24.94}\ (\text{year}) + \underset{(4.59)}{.2111}\ (\text{year})^2$$

$R^2 = .75$ Standard Deviation = 18.29

Dependent variable: Grain sorghum gross returns/acre, Class I land

$$\text{Gross returns/acre} = \underset{(2.22)}{337.04} - \underset{(-2.62)}{12.19}\ (\text{year}) + \underset{(3.28)}{.115}\ (\text{year})^2$$

$R^2 = .82$ Standard Deviation = 14.00

Dependent variable: Grain sorghum gross returns/acre, Class II land

$$\text{Gross returns/acre} = \underset{(2.51)}{334.18} - \underset{(-2.92)}{11.96}\ (\text{year}) + \underset{(3.61)}{.112}\ (\text{year})^2$$

$R^2 = .83$ Standard deviation = 12.30

Variable Cost of Production. Variable inputs necessary for the production of an acre of wheat or grain sorghum were taken from 1980 Oklahoma State Enterprise Budgets. Since Oklahoma State Enterprise Budgets are only available beginning in 1973, the following procedure was used in projecting variable cost to coincide with the years of price and yield data used in generating expected gross returns for the period 1950 to 1980.

Both Oklahoma Enterprise production cost data and United States Department of Agriculture total state expense data are available for the period 1973-1980. Using data from this time period, regression equations for variable cost of production of wheat and grain sorghum were estimated with Oklahoma Budget Enterprise production data the dependent variable and total state expenses for seed, fertilizer, repair (includes fuel and oil), and labor divided by total planted acres in Oklahoma the independent variable (Knowles, 1981). The source for the total state data is various issues of Oklahoma Agricultural Statistics. The estimated equations are given below:

Dependent variable: Oklahoma Enterprise production cost, Wheat, Northcentral Oklahoma

$$\text{Production cost/acre} = \underset{(2.05)}{13.71} + \underset{(4.18)}{55.42}\left(\frac{\text{total state expenses}}{\text{total planted acres}}\right)$$

$R^2 = .78$ Standard deviation = 3.22

Dependent variable: Oklahoma Enterprise production cost, Grain sorghum Northcentral Oklahoma

$$\text{Production Cost/acre} = \underset{(1.31)}{10.12} + \underset{(2.52)}{38.87}\left(\frac{\text{total state expenses}}{\text{total planted acres}}\right)$$

$R^2 = .56$ Standard deviation = 3.73

The above equations were used to extrapolate back to 1950 and generate variable costs of production. The generated variable costs for the period 1950-1972 and actual variable cost data for 1973-1980 were used as data in predicting variable costs for the period 1981-1995. The equations for predicting future variable costs are listed below. T-values are listed in parenthesis below the parameters.

Dependent variable: Oklahoma Enterprise production cost, Wheat, Northcentral Oklahoma

$$\text{Production cost/acre} = \underset{(5.78)}{281.27} - \underset{(-5.94)}{8.87}\,(\text{year}) + \underset{(6.72)}{.0758}\,(\text{year})^2$$

$R^2 = .88$ Standard deviation = 4.49

Dependent variable: Oklahoma Enterprise production cost, Grain Sorghum, Northcentral Oklahoma

$$\text{Production cost/acre} = \underset{(5.58)}{210.12} - \underset{(-5.73)}{6.62}\,(\text{year}) + \underset{(6.45)}{.0564}\,(\text{year})^2$$

$R^2 = .87$ Standard deviation = 3.48

Repair and Maintenance Cost

Repairs are usally the most variable component of machinery cost. Repair costs are influenced by a number of items including (1) management, (2) maintenance level, (3) machine variability, (4) variability in local cost for parts and labor, (5) the effects of climate and soils, (6) operating capacities and time interval at which services are extracted, and (7) the quality of inputs used in combination with the durable (Kletke, 1979; Robison, 1980).

Figure 13 illustrates the reliability of machinery given a certain level of maintenance and repair. A machine given "good" care reaches an unsatisfactory level of reliability at about 80 to 85 percent of its maximum life, while improper maintenance causes an unacceptable level of reliability at slighly higher than 50 percent of its estimated wear-out life.

Repair cost calculations used in this study are based on equations reported in the 1980 Agricultural Engineers Yearbook. These equations are shown in Table II. These equations are based on the accumulated yearly use of the machine (Table III), and the list price (Table IV). Annual machinery usage for each year is based on technical machinery usage coefficients in hours per acre for each activity taken from Oklahoma State University Enterprise Budgets (Table V), and the optimal cropping strategy obtained from the linear programming subsystem. Due to the nature of the projected returns estimated by the forecasting equations, the optimal planting strategy does not change during the replacement decision horizon. Thus, the annual machinery usage is constant in the base solution. Chapter V introduces random returns and variable machinery usage into the decision process by incorporating

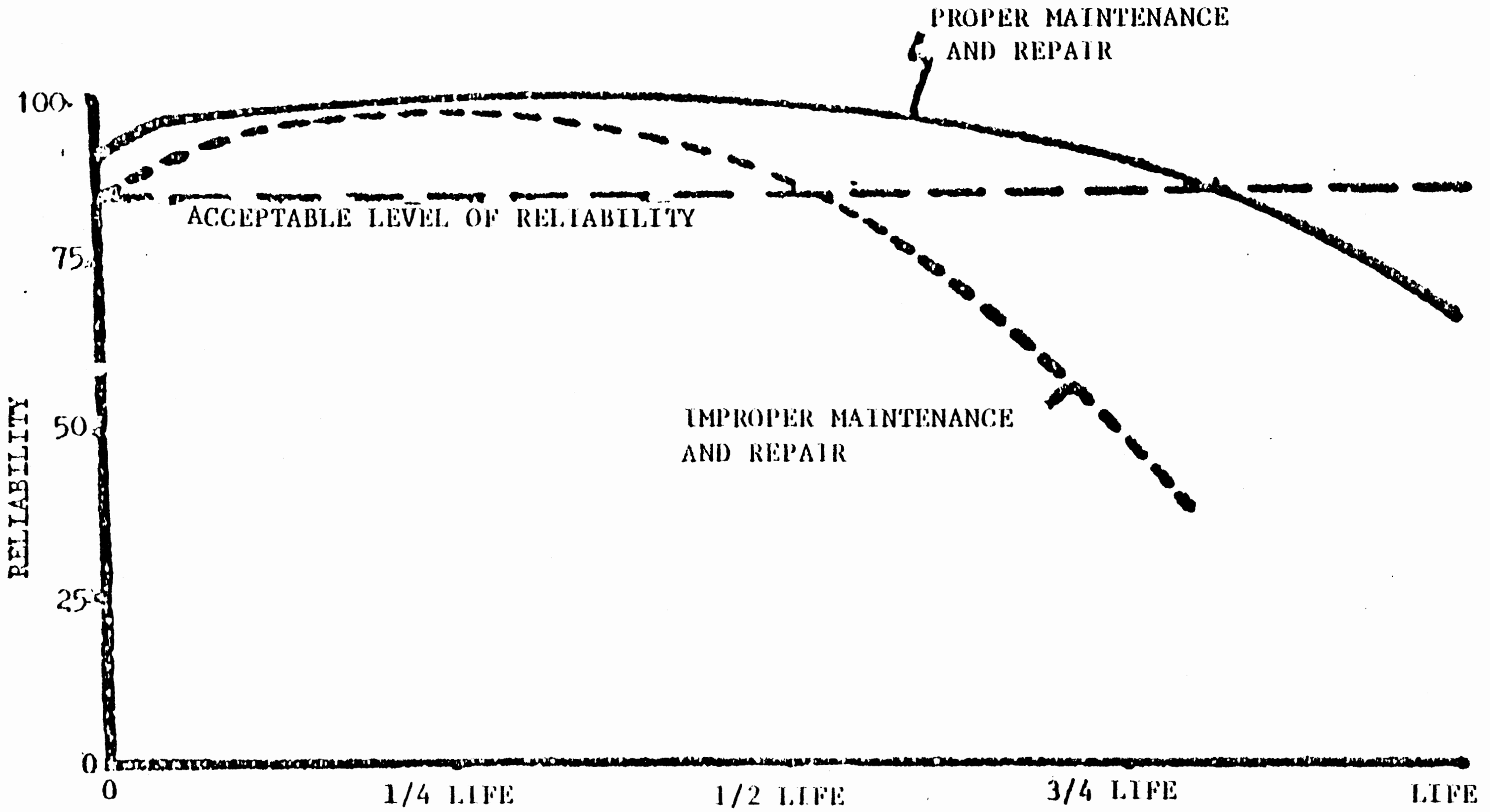


Figure 13. Reliability of Machinery Given a Certain Level of Maintenace

TABLE II

REPAIR AND MAINTENANCE COST EQUATIONS

Machine	Cost Equation[a]
Tractors	
gasoline	$0.0183\ X^{2.159}$
diesel	$0.0120\ X^{2.033}$
LPG	$0.0131\ X^{2.122}$
Moldboard plows	$0.0700\ X^{1.810}$
Disk harrows	$0.0025\ X^{1.714}$
Chisel plows and Field Cultivators	$0.0103\ X^{1.400}$
Grain Drills	$0.0359\ X^{2.626}$
Row Cultivators	$0.0094\ X^{2.207}$
Sprayers	$0.1232\ X^{1.400}$

a. X = accumulated hours/1000 for tractors, acres/1000 for attachments.

Source: American Society of Agricultural Engineers Farm Machinery Management Committee (1980).

TABLE III

MACHINERY USAGE - BASE SOLUTION*

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tractor	914.39	914.39	914.39	914.39	914.39	914.39	914.39	914.39	914.39
Tandum Disk	625	625	625	625	625	625	625	625	625
Moldboard Plow	625	625	625	625	625	625	625	625	625
Field Cultivator	210.67	210.67	210.67	210.67	210.67	210.67	210.67	210.67	210.67
Springtooth	1250	1250	1250	1250	1250	1250	1250	1250	1250
Drill	625	625	625	625	625	625	625	625	625
Row Cultivator	414.33	414.33	414.33	414.33	414.33	414.33	414.33	414.33	414.33
Sprayer	414.33	414.33	414.33	414.33	414.33	414.33	414.33	414.33	414.33

TABLE III (Continued)

	1990	1991	1992	1993	1994	1995
Tractor	914.39	914.39	914.39	914.39	914.39	914.39
Tandum Disk	625	625	625	625	625	625
Moldboard Plow	625	625	625	625	625	625
Field Cultivator	210.67	210.67	210.67	210.67	210.67	210.67
Springtooth	1250	1250	1250	1250	1250	1250
Drill	625	625	625	625	625	625
Row Cultivator	414.33	414.33	414.33	414.33	414.33	414.33
Sprayer	414.33	414.33	414.33	414.33	414.33	414.33

*Usage given in hours for tractor, across for implements.

TABLE IV

LIST PRICES AND TOTAL HOURS OF LIFE FOR THE MACHINERY COMPLEMENT WITH 1981 BASE PERIOD

Machine	List Price	Total Hours of Life
Tractor (95 hp.)	28500	12000
Tandem Disk	3500	2000
Moldboard Plow	4800	2000
Field Cultivator	4300	2000
Springtooth	3200	2000
Drill	4400	1000
Row Cultivator	1700	2000
Sprayer	1200	1000

Source: Oklahoma State University Enterprise Budgets (1981).

TABLE V

TOTAL MACHINERY USAGE COEFFICIENTS IN HOURS PER ACRE OF EACH ACTIVITY IN THE 1981 BASE PERIOD

Machine	Activity	
	Wheat	Grain Sorghum
Tractor	1.408	1.491
Tandem Disk	.143	.148
Moldboard Plow	.381	.381
Field Cultivator	.172	----
Springtooth Harrow	.164	.222
Drill w/o Fertilizer	.215	.215
Row Cultivator	----	.238
Sprayer	----	.151

Source: Oklahoma State University Enterprise Budgets (1981).

probabilities of returns and a random number generator into the replacement model.

Economic Recovery Tax Act of 1981

One of the objectives of the Economic Recovery Tax Act of 1981 was to encourage investment. Tax implications are an important consideration in any machinery investment/disinvestment model in that while sales taxes and business taxes on the resources reduce the net returns to machinery throughout its lifetime, tax deductions and tax credits in turn add to machinery returns. The following section briefly examines the most important aspects of the new tax laws as they relate to machinery investment/disinvestment.

Tax Depreciation Deductions for Machinery

Regular Accelerated Cost Recovery System. The Economic Recovery Tax Act of 1981 speeds up tax depreciation of buildings, machinery, and breeding stock, to allow farmers to recover cost faster. Table VI shows the depreciation schedules under the old and new tax systems. For machinery and equipment which under the old system would be depreciated over eight to 12 years can now be depreciated in five years. Optional depreciation schedules are available if straight line depreciation is used (Table VII).

Table VIII gives the depreciation deduction schedules for business property placed in service for the years 1981 through 1984 under the Regular Accelerated Cost Recovery System. Note that these percentages apply regardless of when in the tax year the property is placed in service. Salvage values are no longer used in calculating

TABLE VI

DEPRECIATION PERIODS UNDER THE OLD AND NEW TAX SYSTEM

Farm Asset	Depreciation Period*	
	Old System	1981 Tax Recovery Act
Cars and light trucks	Variable	3.0
Machinery and equipment	8.0-12.0	5.0
Cotton ginning assets	9.5-14.5	5.0
Cattle, breeding or dairy	5.5-8.5	5.0
Hogs, breeding	2.5-3.5	3.0
Sheep and goats, breeding	4.0-6.0	5.0
Confinement buildings	20.0-30.0	5.0
Other farm buildings	20.0-30.0	15.0

*Unit of measurement is years.

Source: U.S. Department of Agriculture (1981).

TABLE VII

OPTIONAL DEPRECIATION PERIODS UNDER THE STRAIGHT LINE ACRS

Class of Property	Possible Recovery Periods
3 Year Property	3,5,or 12 years
5 Year Property	5,12,or 25 years
10 Year Property	10,25,or 35 years

Source: Mike L. Hardin and Cecil D. Maynard (1981).

TABLE VIII

DEPRECIATION DEDUCTIONS FOR BUSINESS PROPERTY PLACED IN SERVICE 1981 THROUGH 1984

	Type of Property			
Depreciation Year	3-Year	5-Year	10-Year	15-Year
1	25	15	8	12
2	38	22	14	10
3	37	21	12	9
4		21	10	8
5			10	7
6			10	6
7			9	6
8			9	6
9			9	6
10			9	5
11-15				5

Source: U.S. Department of Agriculture (1981).

depreciation deductions. No depreciation is allowed in the year of resource disposition.

Straight-line Accelerated Cost Recovery System. A taxpayer may elect to use the Accelerated Cost Recovery System straight line method over the regular recovery period or the optional longer recovery period. The same recovery period must be used for all personal property of a class for which such an election is made. Thus for the machinery complement being considered in this study which is purchased at the beginning of 1981, the same recovery period must be used for the entire complement.

Annual depreciation under the straight-line system is determined by dividing original cost by the regular or optional longer recovery period (Tables VI and VII). Annual depreciation is determined by dividing the original cost by the regular or optional longer recovery period. First year depreciation is one-half annual depreciation, independent of the date of purchase. The last half year is claimed in the year following the end of the recovery period. No depreciation is allowed in the year of disposition (Hardin, Maynard, 1981).

"Expensing" Depreciable Assets

The new tax laws for the first time allow the owner to "expense", or treat certain types of property purchases as operating expenses and immediately deduct their cost from gross receipts. No investment credit is allowed on such property claimed as an expense. Trust, estates, and certain non-corporate taxpayers and lessors are not eligible. Beginning in 1982 and 1983 the maximum amount that can be expenses is $5000, $7500 in 1984 and 1985, and $10,000 in 1986 and later years (Hardin, Maynard, 1981).

Investment Tax Credits

The new laws continue tax credits given for investment in farm equipment, machinery, livestock, and single-purpose agricultural structures. (A credit, unlike a deduction, is subtracted from the actual tax you owe.) Sixty percent of an investment in three-year recovery property is eligible for the investment credit and 100 percent of an investment in five or greater year recovery property is eligible. For married persons filing joint returns in 1981, the regular investment credit is limited to the income tax shown on the return, or to $25,000 plus 80 percent of tax that is more than $25,000, whichever is less. The percentage of tax that is more than $25,000 increases to 90 percent for 1982 and later years. The new and old tax investment credits are listed below (Table IX).

TABLE IX

OLD AND NEW TAX INVESTMENT CREDITS

Life	Old Law	New Law
3 year	3.33%	6%
5 year	6.66%	10%
7 year or more	10.00%	10%

Source: Mike L. Hardin and Cecil D. Maynard (1980).

Recapture of Investment Credit

The below recapture rules apply to investment credit property in service beginning 1981 (Table X). If a taxpayer disposes of an asset, or it ceases to be eligible before the end of the recapture period for recovery property or before the end of the estimated useful life used to figure the credit for other property, the taxpayer must refigure the credit using a recapture percentage and increase taxes for the year of disposal of the asset by the difference between the credit taken in all affected years and the refigured credit (Federal Tax Guide, 1981).

Machinery Investment/Disinvestment Subsystem

The investment/disinvestment subsystem inputs the results generated by the linear programming subsystem and asset ownership cost subsystem and computes the net returns attributable to machinery which in turn is used in determining the optimal investment/disinvestment strategy given the projected gross returns, variable costs, and other assumptions outlined in this study. The following section outlines the assumptions used in determining the net returns attributable to machinery for the hypothetical farm in Northcentral Oklahoma.

Returns to Machinery

The procedure used to determine returns to machinery in this study is as follows: Projected gross returns and variable cost for the years 1982-1995 were estimated using regression equations with time the independent variable. Subtracting variable cost of production/

TABLE X

RECAPTURE INVESTMENT CREDIT

	Recapture	
Disposed of	3 year	5 year
Within 1 year	6%	10%
After 1 year	4%	8%
After 2 years	2%	6%
After 3 years	0	4%
After 4 years	0	2%
After 5 years	0	0

Source: Mike L. Hardin and Cecil D. Maynard (1981).

acre from gross returns/acre results in returns to land, overhead, risk, management, and machinery. The following assumptions were made in estimating charges for overhead, management and risk, and land, so that returns to machinery could be determined and analyzed in the investment/disinvestment decision model.

Charges for Overhead

Charges for farm overhead expenses assumed in this study where \$9.00 per acre for 1981 in the Southern Plains. Future overhead charges were inflated by $(1+r)^n$ (U.S. Department of Agriculture, 1980a).

Charges for Management and Risk

Charges for mangement and risk were estimated by the following equation:

Management and risk charges = 10% (Variable cost + Machinery Fixed Cost + Overhead) (U.S. Department of Agriculture, 1980a).

Charges for Land

Charges subtracted for land are those being currently charged by landowners in a sharecrop situation for the use of the land in the Southern Plains of Oklahoma. This charge is computed by taking one third of gross receipts from the land minus one third of fertilizer and pesticide cost (Weisgerber, 1980).

Gross Returns to Machinery

Tables XI and XII gives projected gross returns and variable cost of production/acre for the planning horizon 1981-1995. The last

TABLE XI

RETURNS TO PRODUCTION/ACRE OF WHEAT USING PREDICTED GROSS RETURNS AND VARIABLE COST

	Gross Returns		Variable Cost of	Net Returns	
Year	Class I	Class II	Production	Class I	Class II
1981[a]	149.52	134.56	73.54	75.98	61.02
1982	154.22	138.80	63.67	90.55	75.13
1983	165.22	148.70	67.31	97.91	81.39
1984	176.68	159.01	71.10	105.58	87.91
1985	188.62	169.75	75.05	113.57	94.70
1986	201.02	180.92	79.14	121.88	101.78
1987	213.89	192.50	83.39	130.50	109.11
1988	227.23	204.51	87.79	139.44	139.44
1989	241.04	216.94	92.34	148.70	124.60
1990	255.32	229.79	97.05	158.27	132.74
1991	270.07	244.06	101.90	168.17	141.16
1992	285.29	250.91	106.91	178.39	150.00

TABLE XI (Continued)

Year	Gross Returns		Variable Cost of Production	Net Returns	
	Class I	Class II		Class I	Class II
1993	300.98	270.88	112.07	188.91	158.81
1994	317.13	285.57	117.38	199.75	168.19
1995	333.76	300.39	122.84	210.92	177.55

[a] Actual return and cost data for year 1981.

TABLE XII

RETURNS TO PRODUCTION/ACRE OF GRAIN SORGHUM USING PREDICTED GROSS RETURNS AND VARIABLE COST

	Gross Returns		Variable Cost of Production	Net Returns	
Year	Class I	Class II		Class I	Class II
1981[a]	126.00	113.40	51.75	74.25	61.65
1982	113.18	104.52	46.18	67.00	58.34
1983	120.02	111.99	48.86	71.16	63.13
1984	127.09	117.69	51.66	75.43	66.03
1985	134.40	124.61	54.57	79.83	70.04
1986	141.93	131.75	57.59	84.34	74.16
1987	149.69	139.12	60.72	88.97	78.40
1988	157.69	146.71	63.97	93.72	82.74
1989	165.92	154.52	67.33	98.59	87.19
1990	174.37	162.56	70.80	103.57	91.76
1991	183.06	171.05	74.38	108.68	96.67
1992	191.98	179.31	78.08	113.90	101.23

TABLE XII (Continued)

	Gross Returns		Variable Cost of Production	Net Returns	
Year	Class I	Class II		Class I	Class II
1993	201.13	188.01	81.89	119.24	106.12
1994	210.51	196.94	85.81	124.70	111.13
1995	220.12	206.10	89.85	130.27	116.25

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[a] Actual return and cost data for year 1981.

column list returns less variable cost for the two classes of land.

Machinery Cost

Gross returns to machinery are inputted into the investment/disinvestment subsystem which estimates the optimal investment/disinvestment decision. The following costs are computed in this subsystem and subtracted from gross returns to arrive at net returns to machinery. Repair and maintenance costs have already been computed in the repair cost subsystem.

User and Capacity Time Cost. Changes in the market value of the machinery complement are assumed to reflect user and capacity time cost in this study. For the base solution, Agricultural Engineer equations were used in estimating future machinery salvage values (A.S.A.E., 1980). The predicted salvage values are shown in Table XIII.

Control Cost. Funds used to purchase assets are not available for investment elsewhere, thus costs occur. If equity funds are involved, the cost is the foregone earnings on the next best investment opportunity. If borrowed funds are involved, the cost is the interest paid on the loan. Control costs assumed in the base problem are (1) an eight percent opportunity cost times the value of the machinery complement at the beginning of each year, and (2) interest cost computed using a "typical" machinery loan arrangement through the Production Credit Association. Interest rate charges at the time of this study were 16.3 percent on the unpaid balance, for a three year period, with the borrower paying one-third of the principal balance each year plus accrued interest charges.

TABLE XIII

MACHINERY SALVAGE VALUES AS PERCENT OF LIST PRICE[a]

Machine	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tractor	19,077[b]	18,780	18,487	18,198	17,914	17,635	17,360	17,089	16,822
Tandem Disk	1,818	1,721	1,630	1,543	1,461	1,384	1,310	1,241	1,112
Moldboard Plow	2,727	2,582	2,445	2,315	2,192	2,076	1,966	1,861	1,668
Field Cultivator	2,443	2,367	2,190	2,074	1,964	1,860	1,761	1,667	1,495
Springtooth	1,988	1,883	1,783	1,688	1,598	1,514	1,433	1,357	1,216
Drill	2,499	2,367	2,241	2,122	2,009	1,903	1,802	1,706	1,529
Row Cultivator	965	914	866	820	776	735	696	659	591
Sprayer	681	645	611	578	548	519	491	465	417

TABLE XIII (Continued)

Machine	1990	1991	1992	1993	1994	1995
Tractor	16,560	16,303	16,047	15,797	15,550	15,308
Tandem Disk	1,112	1,054	998	945	895	847
Moldboard Plow	1,668	1,581	1,497	1,417	1,342	1,271
Field Cultivator	1,495	1,416	1,341	1,270	1,202	1,139
Springtooth	1,216	1,152	1,091	1,633	979	927
Drill	1,529	1,449	1,372	1,299	1,230	1,165
Row Cultivator	591	560	530	502	476	450
Sprayer	417	395	374	354	335	317

[a] 1980 American Society Engineers Yearbook.

[b] Values in dollar amounts.

Tax Cost. The cost of taxes per hour is based on the purchase price of the machine. Hourly tax costs are computed using the following equation:

Tax cost per hour = Purchase price * Tax Rate/hours used annually

The tax rate assumed is .01 (Oklahoma State University Enterprise Budgets).

Net Returns to Machinery

Subtracting user and capacity time cost, control cost, and insurance cost from the gross returns to machinery results in net returns to machinery excluding tax considerations. By subtracting taxes paid on machinery and adding tax reductions due to machinery depreciation deductions and investment tax credits results in net returns to machinery. The flow of net returns to machinery is inputted into the investment/disinvestment model to determine the optimal economic life of the machinery. The following chapter presents the applications made of the investment/disinvestment model.

CHAPTER IV

MODEL APPLICATION

Base Solution

The base solution of the investment/disinvestment decision model in this study is given in Table XIV. In arriving at this solution 625 acres of land were available for production. By projecting returns using regression equations and assumptions outlined in Chapter III, 210.67 acres of wheat on Class I land, 39.33 acres of grain sorghum on Class I land, and 375 acres of grain sorghum on Class II land was determined to be the profit-maximizing solution by the linear programming subsystem throughout the 15 year horizon. Although the program determines an optimal planting strategy for each year, the planting strategy does not change throughout the 15 years due to the nature of the predicted returns. Variable usage and random returns are incorporated into the model in Chapter V.

Table XIV and the remaining replacement tables in this chapter are set up in the following format. Column 1 lists the period being analyzed. The planning horizon in this study is for the years 1981-1995. Column 2 lists gross returns less variable costs generated throughout the 15 year planning horizon. Gross returns and variable costs were estimated using the forecasting equations outlined in Chapter III. Subtracting returns to land, management, risk, and overhead results in gross returns to machinery given in column 3.

TABLE XIV

MACHINERY INVESTMENT/DISINVESTMENT BASE SOLUTION

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	25785.81	-14570.49	-15736.13	-15736.13
2	43588.89	12215.14	8578.01	-11452.23	3637.13	- 6422.06
3	47099.29	13726.24	8315.30	- 7156.86	5410.93	- 2777.10
4	49970.59	14945.73	5955.47	- 548.76	8990.25	- 165.68
5	53330.57	16054.36	7897.54	5002.63	8156.81	1252.94
6	56803.63	17180.29	13598.00	7260.08	3582.28	1570.47
7	60391.73	18319.14	17450.79	8350.24	1868.34	1603.85
8	64089.48	19464.98	19769.71	8185.60	- 304.73	1424.42
9	67900.56	20617.79	23619.91	6693.79	- 3002.12	1069.94
10	71826.38	21776.07	28035.53	3784.44	- 6259.46	563.99
11	75954.31	22994.13	33109.84	- 554.02	-10115.72	- 77.61
12	80020.44	14090.70	38914.46	- 6440.75	-14823.77	- 854.66
13	84282.50	25234.99	45506.40	-13894.52	-20271.42	- 1757.96
14	88659.75	26369.45	52985.57	-22956.28	-26616.12	- 2784.52
15	93152.13	27489.00	61463.30	-33666.41	-33974.31	- 3933.23

Period costs in column 4 consist of machinery repair and maintenance costs, insurance and taxes on machinery, and user and capacity time costs. Tax savings due to the 1981 Economic Recovery Tax Act are treated as cost reductions and are included in column 4. Column 6 is the net returns to machinery, (column 3 minus column 4) for each period. Column 5 is the present value of net returns (column 6) for the entire life of the machinery complement. For example, the present value in period two given in column 5 is the present value of period net returns in year one and year two, the present value for year three is the present value of total returns up to that period. Column 7 is the amortized multiperiod gain function $Gr/(1-(1+r)^{-s})$ as discussed in Chapter II.

An eight percent discount rate is assumed in this study. The discount rate should represent a value which reflects time preference for a lump sum of money. For income tax purposes the accrual method in which all items of gross income from the farming operation and farm business expenses are included in the tax year in which they are incurred, regardless of when payment is received or paid. A calendar year represents a tax year in this study. A farmer and his wife with two children were assumed to file a joint return in computing tax considerations. The standard depreciation period of five years under the 1981 Tax Recovery Act was chosen in depreciating the machinery complement and a ten percent investment credit was taken in the year of acquisition of the machinery complement.

The investment/disinvestment model utilizes the period returns and the multi-period amortized gain function given in columns 6 and 7 in determining the optimal replacement decision. By comparing the multi-period gain function $Gr(1-(1+r)^{-s}$ in year two, the period returns are greater than the amortized average thus the machinery complement should be kept the first period. This comparison continues (choosing s) until period returns (column 6) are less than the annualized average returns. In year eight, period returns of -304.73 are less than the annualized returns of 1424.42. Thus the machinery complement should not be kept the eighth year since the period returns are now causing the annualized average returns to decrease. Figure 14 shows graphically how the replacement period is determined. Where the marginal returns equals the average returns is the period for replacement. The optimum economic life of the machinery complement is seven years.

Effects of Gross Returns on the Investment/ Disinvestment Decision

The base replacement solution was based on forecasted returns and variable cost computed using a quadratic model $Y = a + b(\text{year}) + c(\text{year}^2)$ using 1950-1981 data. Two different forecasting equations are now inputed into the model to determine the effect of the projected returns being assumed in determing replacement.

Table XV is the replacement decision model with gross returns and variable cost based on 1970-1981 data. The method used for forecasting returns and cost fits a trend model across time such that the most recent data is weighted more heavily than data in the earlier part of the series. The weight is a geometric function of the number of periods past where:

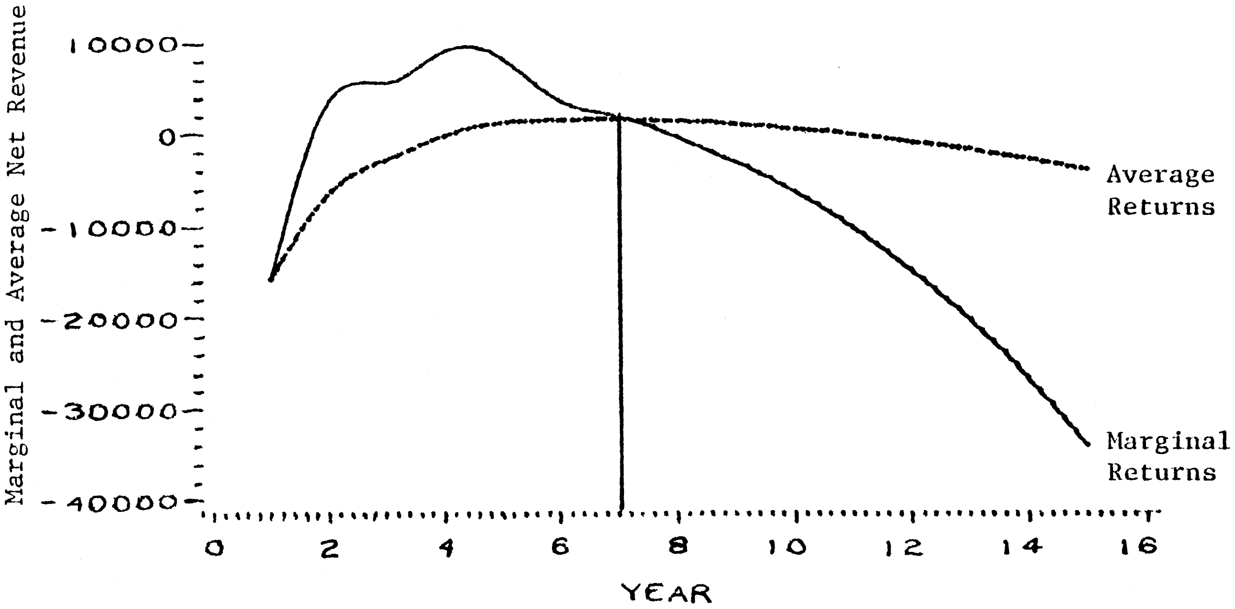


Figure 14. Graph of Base Replacement Solution

TABLE XV

INVESTMENT/DISINVESTMENT MODEL WITH FORECASTED RETURNS BASED ON 1970-1981 WEIGHTED TREND RETURN AND COST DATA

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	25785.81	-14570.49	-15736.13	-15736.13
2	41701.00	9796.26	8732.69	-13658.66	1063.55	- 7659.36
3	43984.14	10382.09	8533.36	-12191.09	1848.72	- 4730.55
4	46263.52	11123.66	6252.04	- 8610.30	4871.62	- 2599.63
5	48547.05	11455.84	8280.22	- 6449.03	3175.61	- 1615.20
6	50824.75	11747.41	13598.00	- 7615.22	- 1850.60	- 1647.29
7	53107.88	12003.29	16450.79	-10210.30	- 4447.51	- 1961.12
8	55387.17	12212.67	19769.71	-14293.13	- 7557.04	- 2487.22
9	59928.30	13885.53	23619.91	-19162.75	- 9734.38	- 3067.57
10	59949.73	12495.43	28035.53	-26360.83	-15540.11	- 3928.54
11	62160.91	12492.73	33109.84	-35203.16	-20617.12	- 4931.13
12	64512.77	12570.02	38914.46	-45644.91	-26344.45	- 6059.50
13	66798.75	12524.24	45506.40	-57792.40	-32982.17	- 7312.00
14	69073.63	12404.33	52985.57	-71608.69	-40581.25	- 8685.91
15	71356.69	12224.54	61463.30	-87130.81	-49238.78	-10179.45

weight = $(1-a)^{T-t}$
t = number of observations
T = last observation number
a = weighted constant = .3

This procedure results in gross returns for wheat increasing approximately 4.49 percent and gross returns of grain sorghum increasing 4.2 percent. Wheat variable costs were forecast to increase at a rate of 4.8 percent and grain sorghum variable costs to increase at 4.5 percent on average.

Comparing columns 1 and 2 of Table XV to those of XIV illustrate the much lower returns generated by using this estimating procedure. Examining columns 6 and 7, period returns in year six of -1850.60 are less than the annualized average of -1747.29, thus the optimal replacement occurs at the end of year five. The reduced net returns forecasted in this simulation reduces the economic life of the machinery complement from seven years found in the base solution to five year. Figure 15 shows graphically how the reduced forecasted returns reduces the economic life of the machinery complement.

Table XVI shows the replacement model based on returns and variable cost being forecasted with a simple linear equation Y = a + b(year) computed based on 1976-1981 data. As evident in columns 1,2, and 5, using this forecasting procedure results in returns to machinery greater than those found in the two previous model applications. Comparing the period returns to the annualized average (columns 6 and 7), period returns in year nine are less than the annualized average, the optimal economic life is therefore eight years. Thus, with greater returns to machinery projected throughout the 15 year period, the economic life of the complement increases from seven to eight years.

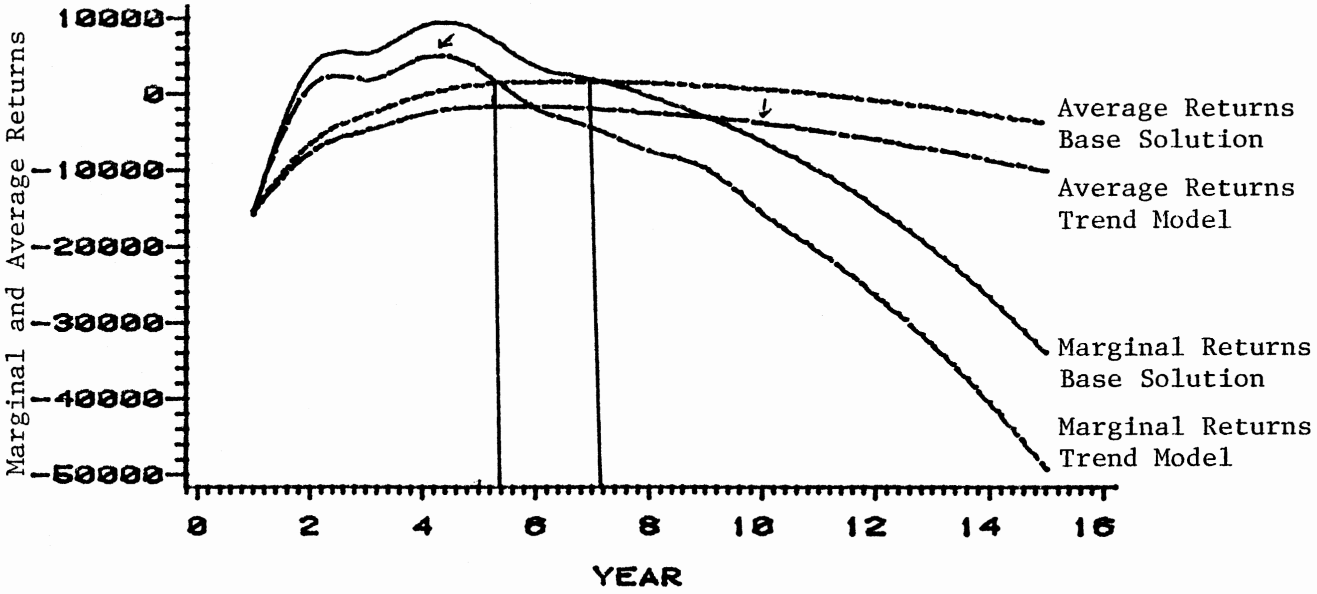


Figure 15. Graph of Base and Trend Model Replacement Solutions

TABLE XVI

INVESTMENT/DISINVESTMENT MODEL WITH FORECASTED RETURNS BASED ON Linear Regression of 1976-81 RETURN AND COST DATA

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	25785.81	-14570.49	-15736.13	-15736.13
2	47810.53	13108.79	8207.62	-10368.53	4901.16	-5814.35
3	52702.99	15054.93	7821.30	- 4626.24	7233.63	- 1795.14
4	57599.57	17166.71	5515.10	3938.04	11651.61	1188.98
5	62472.70	18847.48	7417.78	11716.90	11429.70	2934.57
6	67392.13	20523.79	13598.00	16081.32	6925.77	3478.64
7	72286.69	22142.10	16450.79	19402.13	5691.30	3726.62
8	77181.19	23719.69	19769.71	21536.18	3949.98	3747.61
9	82075.69	25249.92	23619.91	22351.59	1630.00	3578.04
10	86973.69	26734.39	28035.53	21748.90	- 1301.15	3241.23
11	91868.19	28165.00	33109.84	19628.14	- 4944.85	2749.44
12	96764.81	29541.13	38914.46	15905.85	- 9373.34	2110.63
13	101657.70	30855.25	45506.40	10518.64	-14651.16	1330.84
14	106557.60	32110.44	52985.57	3411.47	-20875.14	413.80
15	111453.80	33293.75	61463.30	- 5468.76	-28169.56	- 638.91

The Effect of Farm Size on the Investment/ Disinvestment Model

The base solution assumed a farm size of 625 acres in determining the optimal economic life of the machinery complement. The following two simulations examine the effect on the replacement decision of increasing and decreasing farmland 100 acres.

Table XVII illustrates the replacement model when 100 acres of Class II land is sold or removed from production. With land constraints of 250 acres of Class I land and 275 acres Class II land, the optimal planting strategy for the 15 year period is 239.88 acres wheat on Class I land, 10.11 acres sorghum on Class I land, and 275 acres grain sorghum on Class II land. Comparing Table XVII with the base solution (Table XIV), the optimal economic life of the machinery complement with 100 less acres increases from seven years to nine years. Nine years is the economic optimum because period returns of 410.46 in column 6 in year ten are less than the annualized average of 1737.49. The reasons for the increase in the economic life can be determined by examining the lower gross returns (columns 1 and 2) and the lower repair and maintenance cost reflected in column 4. Examining column 6, net returns to machinery are less in earlier years due to lower production but higher in later years due to lower repair and maintenance cost attributable to less machinery usage. The annualized average (column 7) is a time-corrected average return which reflects the lower early returns and higher later returns. This change in the annualized returns results in a longer economic life and is shown graphically in Figure 16.

TABLE XVII

INVESTMENT/DISINVESTMENT MODEL WITH A DECREASE OF 100 ACRES FARMLAND

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	35931.24	8299.24	26038.13	-16424.91	-17738.90	-17738.90
2	38442.87	11054.12	8416.59	-14163.65	2637.52	- 7942.54
3	41567.76	12452.11	7646.17	-10348.55	4805.93	- 4015.59
4	44248.38	13698.05	4674.75	- 3716.16	9023.29	- 1121.98
5	47312.24	14771.74	5881.27	2334.55	8890.46	584.70
6	50484.30	15867.26	10458.32	5743.09	5408.93	1242.32
7	53764.98	16981.04	12342.01	8449.92	4639.03	1623.00
8	57151.13	18109.83	14544.40	10382.20	3576.51	1806.66
9	60645.46	19251.05	17079.36	11468.58	2171.69	1835.89
10	64248.42	20404.73	19994.26	11658.70	410.46	1737.49
11	68025.19	21609.43	23348.92	10912.66	-1739.50	1528.61
12	71781.13	22733.74	27190.38	9142.86	-4456.64	1213.21
13	75705.81	23900.26	31548.71	6330.54	-7648.45	800.95
14	79739.25	25065.80	36493.55	2439.83	-11427.76	295.94
15	83883.19	26225.70	42103.55	- 2565.54	-15877.86	- 299.73

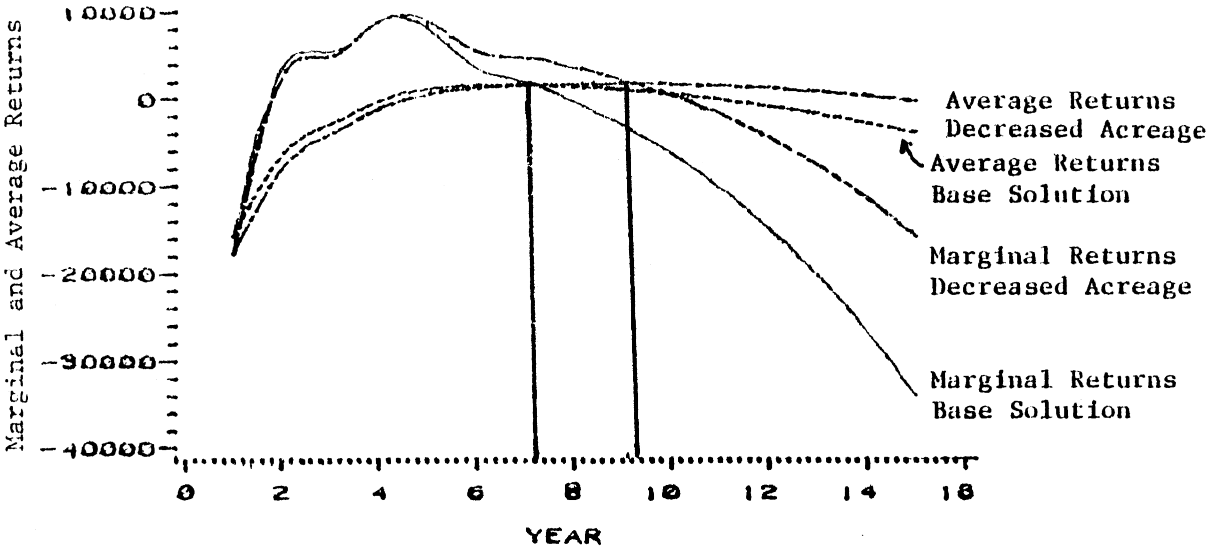


Figure 16. Graph of Base and Decreased Acreage Solutions

Table XVIII shows the replacement model with an addition of 100 acres from that in the base solution. Labor constraints were increased in order to allow for the additional acreage. The optimal planting strategy throughout the projected 15 year period was estimated by the linear programming subsystem to be 266.96 acres wheat on Class I land, 8.41 acres grain sorghum on Class II land, and 445.8 acres grain sorghum on Class II land. Comparing Table XVIII with the base solution, it is apparent that the increased acreage increases machinery repair and maintenance cost due to the increased usage. Column 6 illustrates that with increased usage, earlier net returns to machinery are higher due to the increased gross returns, but later years are lower due to the increased repair and maintenance cost. The time-preferenced annualized average returns (column 7) takes into account this change resulting in a shorter economic life. Period returns (colum 6) in year seven of 408.84 are less than the multi-period gain function 2497.67, thus the optimal economic life is six years, one year less than determined in the base solution.

The Effect of Salvage Values on the Investment/Disinvestment Model

Salvage values in the base solution were estimated using 1980 Agricultural Engineer equations (Table XIII). In order to examine the effect of changing market values of the machinery complement, which represents user and capacity time cost in this study, future salvage values were computed based on 1980 Blue Book Values. In order to estimate salvage values for the tractor, an actual model similar in list price, horsepower, and technical coefficients was

TABLE XVIII

INVESTMENT/DISINVESTMENT MODEL WITH AN INCREASE OF 100 ACRES FARMLAND

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	48364.35	11449.35	25562.55	-13067.78	-14113.20	-14113.20
2	50719.95	14317.21	8558.60	- 8130.71	5758.60	- 4559.45
3	54853.60	16077.13	8874.75	- 2413.23	7202.38	- 936.41
4	58228.33	17456.93	7377.72	4995.29	10079.38	1508.18
5	62184.32	18779.39	10144.34	10872.16	8635.05	2723.00
6	66275.69	20124.05	17119.93	12765.26	3004.12	2761.32
7	70504.31	21486.07	21077.22	13003.81	408.84	2497.67
8	74863.88	22858.18	25685.02	11476.55	-2826.85	1997.09
9	79358.88	24240.74	31029.79	8080.33	- 6789.05	1293.50
10	83991.13	25632.22	37196.26	2736.44	-11537.05	407.81
11	88864.00	27096.38	44222.72	- 4608.77	-17126.34	- 645.58
12	93664.31	28420.21	52290.80	-14088.11	-23870.59	- 1869.42
13	98698.19	29802.75	61462.35	-25729.30	-31659.61	- 3255.32
14	103869.50	31177.44	71872.56	-39584.45	-40695.23	- 4801.47
15	109178.70	32536.94	83671.44	-55704.21	-51134.57	- 6507.90

selected. The tractor selected was a Massey Ferguson 2675 Diesel eight-speed Western. To obtain salvage values for implements using the Blue Book, the factory list price of the machine is used as an index for the miscellaneous implement valuation schedule found in the Blue Book (Falconer, 1980). Since Blue Book values are for only ten years, the last five years of the replacement horizon were estimated using simple linear regression equations based on the first ten years. Table XIX list the estimated salvage values.

The investment/disinvestment model with the new salvage values is given in Table XX. The optimal replacement period does not change from that determined in the base solution using agricultural engineer equations. In year eight the period returns of -11-.62 is less than the annualized average of 1245.86, thus the optimal economic life remains at seven years. The column of interest in this simulation is column 4, period cost. Because of flucturating salvage values, machinery ownership cost may decrease from one period to the next even though repair and maintenance cost continue to rise with age and use. Machinery cost increase from 9488.59 to 12537.44 in years two and three due to machinery depreciation, however machinery ownership cost actually decrease from $15028.55 in year six to $14901.43 in year seven due to machinery appreciation.

The Effect of Repair Cost on the Investment/Disinvestment Model

Repair and maintenance cost are one of the largest costs associated with the ownership of farm machinery and vary widely depending upon (1) weather, (2) mangement, (3) use, (4) repair labor charges, and

TABLE XIX

MACHINERY SALVAGE VALUES BASED ON BLUE BOOK VALUES

	1981	1982	1983	1984	1985	1986	1987	1988
Tractor	23415	22506	19998	18081	17192	15988	15346	14629
Tandum Disk	2037	1936	1776	1647	1352	1195	1383	1286
Moldboard Plow	3018	2964	2695	2342	2013	1736	1948	1875
Field Cultivator	2719	2692	2397	2108	1811	1594	1802	1886
Springtooth	2205	2190	1530	1720	1489	1284	1510	1446
Drill	2782	2722	1963	2196	1852	1594	1753	1886
Row Cultivator	1130	1058	965	878	724	664	701	696
Sprayer	826	726	698	600	483	442	535	535

TABLE XIX (Continued)

	1989	1990	1991	1992	1993	1994	1995
Tractor	13970	13831	11420	10323	9219	8115	7011
Tandum Disk	1120	1102	899	792	686	580	473
Moldboard Plow	1709	1750	1346	1190	1034	878	722
Field Cultivator	1750	1621	1367	1245	1123	1001	879
Springtooth	1296	1296	1074	979	884	789	694
Drill	1750	1820	1820	1457	1247	1142	1037
Row Cultivator	613	674	505	450	395	340	295
Sprayer	471	453	370	333	296	259	222

TABLE XX

INVESTMENT/DISINVESTMENT MODEL WITH BLUE-BOOK SALVAGE VALUES

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10045.69	19890.26	- 9115.40	- 9844.57	- 9844.57
2	43588.89	12212.14	9488.59	- 6780.34	2723.54	- 3802.21
3	47099.29	13725.24	12537.44	- 5837.44	1187.89	- 2265.12
4	49970.59	14945.73	7631.35	- 461.15	7314.38	- 139.23
5	53300.57	16055.36	9686.24	3873.56	6369.11	970.16
6	56803.63	17182.29	15038.55	5224.47	2143.73	1130.13
7	60391.73	18320.14	14901.43	7219.25	3418.71	1386.62
8	64089.48	19465.98	19576.59	7159.49	- 110.62	1245.86
9	67900.56	20619.79	24270.72	5333.11	- 3650.94	853.72
10	71826.38	21777.07	27237.93	2803.67	- 5460.86	417.83
11	75954.31	22997.13	35983.91	- 2766.15	-12986.79	- 387.47
12	80020.44	24093.70	39838.86	- 9018.77	-15745.17	- 1196.75
13	84282.50	25238.99	46193.52	-16723.72	-20954.54	- 2115.92
14	88659.75	26374.45	53484.50	-25953.64	-27110.05	- 3148.10
15	93152.13	27495.00	61857.56	-36786.17	-34362.57	- 4297.71

(5) parts cost. Although the equations estimated in the Agricultural Engineer Yearbook have a high R^2 (greater than .9), studies have estimated that repair and maintenance cost may range from 50 to 200 percent of cost estimated by the repair equations (A.S.A.E., 1980). To examine the effects of different repair costs assumed in the model, repair costs of 50, 75, 150, and 200 percent of those estimated in the base solution were computed into the model. The results are as follows.

Table XXI shows the replacement model with repair and maintenance costs at 50 percent of those estimated in the base solution (Table XIV). Column 4 illustrates how smaller repair and maintenance costs change the total machinery ownership cost as the machinery complement ages and total accumulated usage increases. During the first three years, a 50 percent decrease in repair cost decreases total machinery cost very little; however, as the durables age and total accumulated usage increases period costs are significantly lower with the lower repair cost. Examining the period returns and the multi-period gain function, repair and maintenance cost increase the optimal economic life of the machinery complement from seven years determined in the base solution to ten years.

Table XXII illustrates the replacement model with repair and maintenance cost set at 75 percent of those used in the base solution. As with the 50 percent decrease, the reduced repair cost affect earlier net returns very little, while later years the period returns (column 6) are much higher with lower repair and maintenace cost. Since column seven is a time-preferenced annualized average of returns the unchanged early returns and the higher later returns

TABLE XXI

REPLACEMENT MODEL WITH REPAIR AND MAINTENANCE COST 50 PERCENT OF THOSE ESTIMATED IN BASE SOLUTION

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	25488.07	-14294.80	-15438.38	-15438.38
2	43588.89	12215.14	7586.34	-10326.35	4628.79	- 5790.70
3	47099.29	13726.24	6528.88	- 4612.86	7197.35	- 1789.94
4	49970.59	14945.73	3223.80	4003.10	11721.91	1208.62
5	53330.57	16054.36	4070.12	12159.37	11984.23	3045.39
6	56803.63	17180.29	8696.36	17505.68	8483.93	3786.75
7	60391.73	18319.14	10072.39	22317.58	8246.75	4286.59
8	64089.48	19464.98	11680.75	26523.16	7784.23	4615.42
9	67900.56	20617.79	13560.13	30053.75	7057.66	4811.00
10	71826.38	21776.07	15715.36	32861.03	6060.71	4897.26
11	75954.31	22994.13	18207.16	34914.07	4786.96	4890.64
12	80020.44	24090.70	21071.37	36113.09	3019.32	4792.03
13	84282.50	25234.99	24325.54	36447.49	909.44	4611.40
14	88659.75	26369.45	28025.98	35883.50	- 1656.54	4352.55
15	93152.13	27489.00	32236.17	34386.99	- 4747.18	4017.42

TABLE XXII

REPLACEMENT MODEL WITH REPAIR AND MAINTENANCE COST 75 PERCENT OF THOSE ESTIMATED IN BASE SOLUTION

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	25636.94	-14432.64	-15587.25	-15587.25
2	43588.89	12215.14	8082.17	-10889.29	4132.96	- 6106.38
3	47099.29	13726.24	7433.41	- 5893.84	6292.82	- 2287.01
4	49970.59	14945.73	4574.86	1729.06	10370.86	522.04
5	53330.57	16054.36	5978.40	8586.58	10075.95	2150.57
6	56803.63	17180.29	11147.18	12388.46	6033.11	2679.82
7	60391.73	18319.14	13261.59	15339.50	5057.55	2946.29
8	64089.48	19464.98	15725.22	17359.97	3739.75	3020.69
9	67900.56	20617.79	18590.01	18374.36	2027.77	2941.36
10	71826.38	21776.07	21875.45	18328.32	- 99.38	2731.46
11	75954.31	22994.13	25658.50	17185.61	- 2664.38	2407.30
12	80020.44	24090.70	29992.92	14841.75	- 5982.23	1969.43
13	84282.50	25234.99	34915.96	11282.07	- 9680.98	1427.43
14	88659.75	26369.45	40505.77	6469.20	-14136.33	784.69
15	93152.13	27489.00	46849.73	365.88	-19360.74	42.75

result in the increase of the optimal economic life of the complement from seven to eight years.

The results of increasing repair and maintenance costs 150 and 200 percent above the base solution are shown in Tables XXIII and XXIV. The increase in repair and maintenance costs change period returns negligibly the first few years of life, but as the machinery ages, repair and maintenance costs escalate and cause period returns to machinery to decrease at a much faster rate. The annualized average incorporates this pattern and in both cases the optimal economic life of the machinery complement decreases to five years from the seven year life determined in the base solution. Figure 17 graphically presents the marginal and average net return curves with a 50 percent decrease in repair cost from those in the base solution and a 100 percent increase in forecasted repair and maintenance cost from the base solution.

Effects of Incorporating Tax Considerations Into the Investment/Disinvestment Model

One purpose of the 1981 Economic Recovery Tax Act was to encourage investment. The base solution included the tax regulations under the 1981 Economic Recovery Tax Act by using a five year standard accelerated recovery period, a ten percent investment credit in the year of acquisition, and the new tax tables. Two simulations are now presented in order to examine the effects of taxes on the replacement model and specifically the effect(s) of the 1981 Economic Recovery Tax Act on investment.

The first simulation (Table XXV) illustrates the investment model

TABLE XXIII

REPLACEMENT MODEL WITH REPAIR AND MAINTENANCE COST 150 PERCENT OF THOSE ESTIMATED IN BASE SOLUTION

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	26083.56	-14846.18	-16033.87	-16033.87
2	43588.89	12215.14	9556.47	-12566.80	2658.66	- 7047.07
3	47099.29	13726.24	10079.08	- 9671.57	3647.15	- 3752.90
4	49970.59	14945.73	8716.71	- 5093.06	6229.01	- 1537.70
5	53330.57	16054.36	11823.16	- 2213.39	4231.18	- 554.36
6	56803.63	17180.29	18499.65	- 3044.81	- 1319.37	- 658.64
7	60391.73	18319.14	22829.20	- 5676.39	- 4510.06	- 1090.28
8	64089.48	19464.98	27858.67	-10211.25	- 8393.70	- 1776.91
9	67900.56	20617.79	33679.67	-16745.45	-13061.89	- 2680.61
10	71826.38	21776.07	40355.70	-25351.42	-18579.64	- 3778.11
11	75954.31	22994.13	48012.52	-36081.39	-25018.39	- 5054.15
12	80020.44	24090.70	56757.55	-49053.86	-32666.86	- 6599.20
13	84282.50	25234.99	66687.19	-64295.79	-41452.27	- 8134.82
14	88659.75	26369.45	77944.94	-81855.25	-51575.59	- 9928.79
15	93152.13	27489.00	90690.25	-101778.94	-63201.32	-11890.79

TABLE XXIV

REPLACEMENT MODEL WITH REPAIR AND MAINTENANCE COST 200 PERCENT OF THOSE ESTIMATED IN BASE SOLUTION

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	26381.30	- 15121.87	-16331.62	-16331.62
2	43588.89	12215.14	10512.40	- 13662.05	1702.73	- 7661.25
3	47099.29	13726.24	11842.99	- 12167.07	1883.24	- 4721.23
4	49970.59	14945.73	11462.07	- 9606.48	3483.64	- 2900.40
5	53330.57	16054.36	15713.95	- 9374.81	340.39	- 2347.98
6	56803.63	17180.29	23401.30	- 13295.11	- 6221.02	- 2875.94
7	60391.73	18319.14	29207.61	- 19648.43	-10888.47	- 3773.92
8	64089.48	19464.98	35947.63	- 28553.50	-16482.66	- 4968.73
9	67900.56	20617.79	43739.45	- 40120.10	-23121.66	- 6422.41
10	71826.38	21776.07	52675.88	- 54432.70	-30899.81	- 8112.07
11	75954.31	22994.13	62915.20	- 71554.19	-39921.08	-10023.05
12	80020.44	24090.70	74600.44	- 91612.31	-50509.79	-12156.49
13	84282.50	25234.99	87867.94	-114642.34	-62633.02	-14504.75
14	88659.75	26369.45	102904.50	-140699.57	-76535.13	-17066.41
15	93152.13	27489.00	119917.40	-169836.73	-92428.44	-19841.96

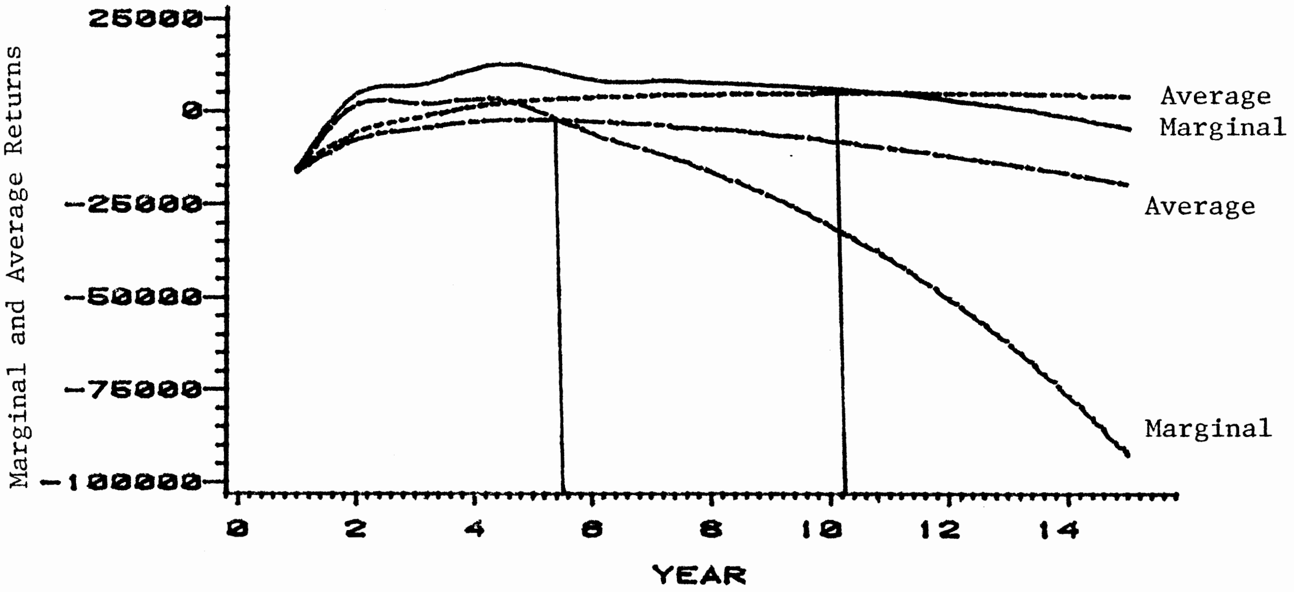


Figure 17. Graph of 50% Decrease and 100% Increase in Repair Cost

TABLE XXV

INVESTMENT/DISINVESTMENT MODEL WITHOUT TAKING TAXES INTO CONSIDERATION

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	33201.36	- 21436.73	-23151.67	-23151.68
2	43588.89	12215.14	11640.41	- 20943.99	574.73	-11744.75
3	47099.29	13726.24	11276.63	- 18999.42	2449.60	- 7372.41
4	49970.59	14945.73	9140.68	- 14732.54	5805.04	- 4448.06
5	53330.57	16054.36	11179.47	- 11414.77	4874.88	- 2858.90
6	56803.63	17180.29	13598.00	- 9157.32	3582.28	- 1980.87
7	60391.73	18319.14	16450.79	- 8067.16	1868.34	- 1549.48
8	64089.48	19464.98	19769.71	- 8231.80	- 304.73	- 1432.45
9	67900.56	20617.79	23619.91	- 9733.61	- 3002.12	- 1558.15
10	71826.38	21776.07	28035.53	- 12632.95	- 6259.46	- 1882.68
11	75954.31	22994.13	33109.84	- 16971.41	-10115.72	- 2377.29
12	80020.44	24090.70	38914.46	- 22858.14	-14823.77	- 3033.16
13	84282.50	25234.99	45506.40	- 30311.91	-20271.42	- 3835.12
14	88659.75	26369.45	52985.57	- 39373.67	-26616.12	- 4775.90
15	93152.13	27489.00	61463.30	- 50083.80	-33974.31	- 5851.27

without taking taxes into consideration. Tax savings were treated as cost reductions and incorporated in the period cost (column 4) in the previous simulations. The tax savings that occur in the first five years due to the ten percent investment credit and the depreciation allowances determined in the base solution are unaccounted for in Table XXV. The optimal replacement period increases from seven to eight years when tax considerations are not accounted for in the model. This is because the multi-period annualized average (column 7) starts much lower due to the tax savings being unaccounted for, thus the time it takes for period returns (column 6) to cause a decrease in the annualized average increases.

Table XXVI presents the investment/disinvestment model based on tax regulations prior to the 1981 Economic Recovery Tax Act. For this simulation, a 6.667 investment credit is taken in the year of acquisition and a declining balance depreciation method over eight years was used in depreciating the asset. A $6000 salvage value for the machinery complement was assumed at the end of eight years. Examining columns (6) and (7), the optimal economic life determined for the machinery complement is seven years. Straight line and sum of the years digits depreciation schedules were simulated and also resulted in an economic life of seven years.

The following conclusions may be drawn from the above simulations. A one-period error resulted by not incorporating the effects of investment credits and depreciation allowances into the solution of the optimal investment/disinvestment decision. However, the 1981 Economic Recovery Tax Act did not decrease the investment/disinvestment period from that determined based on prior tax regulations and tax tables.

TABLE XXVI

INVESTMENT/DISINVESTMENT MODEL BASED ON OLD TAX REGULATIONS

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	42045.69	10049.69	26345.56	-15097.11	-16304.88	-16304.88
2	43588.89	12215.14	8705.86	-12088.48	3509.27	- 6788.85
3	47099.29	13726.24	8765.04	- 8150,12	4961.20	- 3162.52
4	49970.59	14945.73	6917.38	- 2249.04	8028.34	- 679.03
5	53330.57	16054.36	9446.57	2248.10	6607.77	563.05
6	56803.63	17180.29	12298.23	5324.63	4882.06	1151.80
7	60391.73	18319.14	15476.28	6983.41	2842.86	1351.80
8	64089.48	19464.98	19391.79	7022.94	73.18	1222.10
9	67900.56	20617.79	23619.91	5521.13	- 3002.12	883.82
10	71826.38	21776.07	28035.53	2621.78	- 6259.46	390.72
11	75954.31	22994.13	33109.84	- 1716.68	-10115.72	- 240.47
12	80020.44	24090.70	38914.46	- 7603.41	-14823.77	- 1008.93
13	84282.50	25234.99	45506.40	-15057.17	-20271.42	- 1905.06
14	88659.75	26369.45	52985.57	-24118.93	-26616.12	- 2925.55
15	93152.13	27489.00	61463.30	-34829.07	-33974.31	- 4069.06

The 1981 Act did increase the present value of the returns to machinery by $16,416 over the returns in the model without taxes, changing the present value of the machinery complement in the year of replacement from negative to positive. The model simulation (base solution) incorporating the 1981 Economic Recovery Tax Act also increased the present value of returns to machinery $1,163 over the model based on past tax regulations, however the optimal economic replacement period did not change. This is illustrated graphically in Figure 18.

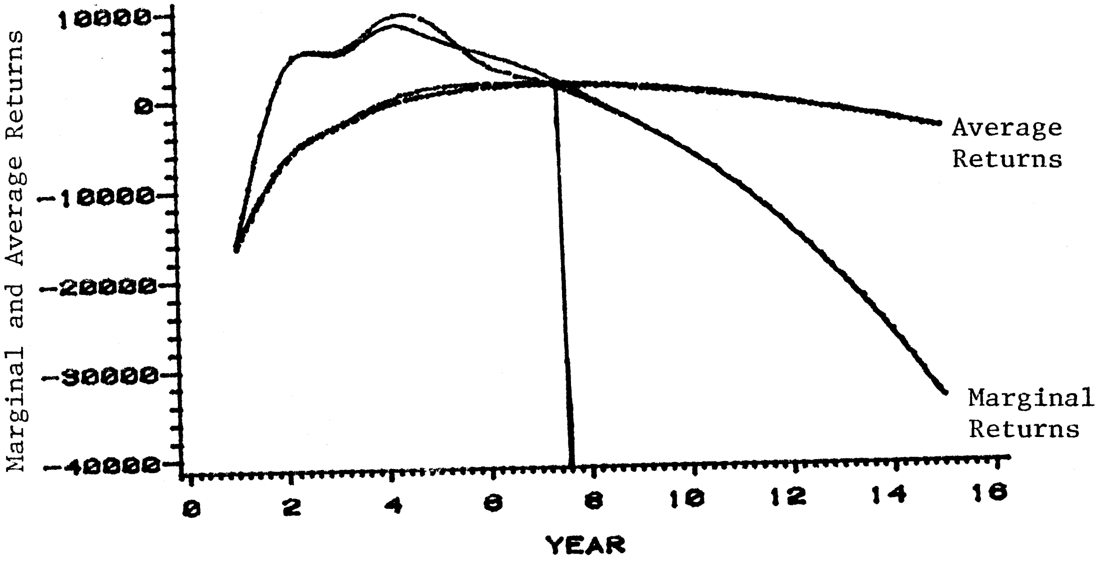


Figure 18. Graph of Replacement Solutions with Old and New Tax Regulations.

CHAPTER V

MODEL SIMULATION INCORPORATING VARIABLE USAGE AND RANDOM RETURNS

The investment/disinvestment decision base solution and the sensitivity test presented in Chapter IV were based on the assumptions that forecasted costs and returns were known with perfect knowledge, i.e. the probability of each variable was assumed to be one. However in the real world this assumption is not true. The following simulations incorporate variable machinery usage and random returns into the replacement decision by the use of a random number generator to produce probability distributions.

Assignment of Probabilities

Gross returns, repair and maintenance costs, and machinery salvage values were allowed to vary in the simulations model by specifying probabilities of the predictions and generating random numbers. Probabilities for gross returns were estimated by utilizing information about the mean and the standard error of the regression equation and assuming a normal distribution about the mean. The projected return from the forecasting equation in Chapter III was assumed to be the mean return. Using this method it was assumed that eleven returns were possible. A probability of occurence was assigned to each return by calculating z values z_1 and z_2, representing plus and minus half the distance between returns and determining the area under the normal curve for this interval.

The probabilities and percent of forecasted return for wheat and grain sorghum are listed in Tables XXVII and XXVIII. Since the normal distribution is symmetrical about the mean, the probabilities for the lower half of the distribution are identical to those in the upper half. The probabilities of all returns sum to one. The replacement model assumes gross returns are independent from one year to the next and that gross returns from Class I and Class II land are dependent. Gross returns for wheat are assumed to be independent with returns for grain sorghum. For example, in year one the model generates random numbers and selects a gross return for Class I wheat and Class I grain sorghum according to the probabilities just outlined. If the returns in this year estimated for Class I wheat are .8 of the projected return for wheat and 1.18 times the projected return for grain sorghum, returns for wheat grown on Class II land is also 80 percent of the projected Class II return and returns for grain sorghum grown on Class II land are 118 percent of the projected Class II returns. The next year new random numbers are generated and returns chosen based on the new random numbers.

The investment model also allows for varying repair and maintenance cost and varying machinery salvage values. Because the mean and standard deviation were not available for the Agricultural Engineer repair and maintenance cost equations, the mean and standard error for the variable cost equations were used in estimating probabilities. The probabilities estimated for repair and maintenance cost are .44 that cost are those determined by the Agricultural Engineer equation, .24

TABLE XXVII

PROBABILITIES AND PERCENT OF FORECASTED RETURN FOR WHEAT GROSS RETURNS/ACRE

Percent of Forecasted Return	Probability
0	.003
20	.015
40	.049
60	.117
80	.198
100	.236
120	.198
140	.117
160	.049
180	.015
200	.003

TABLE XXVIII

PROBABILITIES AND PERCENT OF FORECASTED RETURN FOR GRAIN SORGUM GROSS RETURNS/ACRE

Percent of Forecasted Return	Probability
10	.004
28	.018
46	.056
64	.120
82	.192
100	.220
118	.192
136	.120
154	.056
172	.018
190	.004

probability that cost is eight percent higher than those estimated and .04 probability that repair costs are 17 percent above the projected cost. Likewise, the probability is .24 that costs may be 92 percent and .04 that cost will be 83 percent of those projected in any given year. The probabilities for salvage values assumed in this study were .4 that salvage values will be as estimated, .3 that salvage values will be 90 percent of that predicted, and .3 that salvage values will be 110 percent of the predicted value in any given year.

The Random Number Generator

The random number generator RANF by Chandler (1970) of the Oklahoma State University Computer Science Department was incorporated in the machinery replacement model in order to simulate random returns, cost, and variable machinery usage. This Fortran function subprogram generates pseudo-random numbers, uniformly distributed on the interval (0,1). The procedure which generates the numbers is a composite method whereby the numbers from one generator are used to shuffle the numbers from a second. This method is the most reliable known and has been subjected to the test of randomness (Chandler, 1970). The generator also passes the Chi-square test of randomness conducted by the author.

Variable Returns and Machinery Usage

The returns less variable cost and optimal planting strategy for one simulation are shown in Table XXIX. Columns 2 through 5 give returns less variable cost/acre based on the probabilities specified and the random numbers generated in this simulation. Note that during the 15 year planning horizon returns less variable cost/acre of wheat

TABLE XXIX

EXAMPLE OF VARIABLE RETURNS AND VARIABLE CROPPING

	Net Returns Per Acre				Acres Planted				
Year (1)	WheatI (2)	WheatII (3)	SorghumI (4)	SorghumII (5)	WheatI (6)	WheatII (7)	SorghumI (8)	SorghumII (9)	Net Profit (10)
1	105.88	87.93	96.93	82.06	210.67	0	39.33	375.00	56892.18
2	121.39	102.89	5.88	1.90	250.00	54.35	0	0	35940.34
3	130.95	111.13	49.56	42.97	210.67	0	39.33	375.00	45651.90
4	-0.43	-7.50	98.31	87.21	0	0	250.00	165.38	39000.42
5	189.02	162.60	152.41	137.33	210.67	0	39.33	375.00	97313.06
6	121.88	101.78	7.70	3.01	250.00	54.35	0	0	36001.53
7	173.28	147.61	62.03	53.36	210.67	0	39.33	375.00	58953.76
8	93.99	75.82	122.10	109.15	209.62	0	40.38	375.00	65564.13
9	293.32	254.76	38.86	31.56	250.00	54.35	0	0	87176.81
10	5.08	-5.13	72.18	62.50	0	0	250.00	165.38	28382.23
11	222.18	189.77	207.53	189.04	210.67	0	39.33	375.00	125858.50
12	178.38	150.00	183.01	165.78	209.62	0	40.38	375.00	106950.10
13	309.30	267.16	227.85	207.65	210.67	0	39.33	375.00	151989.00
14	199.75	168.19	162.59	146.58	210.67	0	39.38	375.00	103443.30
15	344.42	297.71	51.03	42.05	250.00	54.35	0	0	102285.40

produced on Class I land range from a high of 309.30 in period 13 to a low of -.43/acre in period four. Returns less variable cost/acre of grain sorghum on Class I land has a high of 227.85 in period 14 and a low of 5.88 in period two. Returns less variable cost for the farm (column 10) ranged fom a high of $151,989 in period 13 to a low of $28,382 in period 15. Returns will be different in each year and in each simulation due to the random numbers generated.

Columns 6-9 give the optimal planting strategy determined by the linear programming subsystem. The linear programming subsystem determined optimal production for each period based on the random returns generated for that period. Thus perfect knowledge was assumed of the random returns in determining crop production while imperfect knowledge was assumed in making machinery replacement decisions. Note how optimal planting changes in responce to the predicted returns less variable cost. In periods two, six, nine, and 15 the acreage shifts to wheat as much as the constraints allow due to the relatively higher returns for wheat in these years. In periods four and 10 only grain sorghum is produced. From 1960-81 grain sorghum was more profitable in Northcental Oklahoma eight of the 21 years, while in this simulation grain sorghum is projected to be more profitable to produce than wheat in four of the 15 years. Table XXX illustrates the variability in machinery usage that occurs when random returns are generated.

TABLE XXX

MACHINERY USAGE BASED ON VARIABLE PROJECTED RETURNS

	1981	1982	1983	1984	1985	1986	1987	1988
Tractor*	914.39	428.52	914.39	619.33	914.39	428.52	914.39	914.47
Tandum Disk	625	304.35	625	415.38	625	304.35	625	625
Moldboard Plow	625	304.35	625	415.38	625	304.35	625	625
Field Cultivator	210.67	304.35	210.67	0	210.67	304.35	210.67	209.62
Springtooth	1250	608.7	1250	830.76	1250	608.70	1250	1250
Drill	625	304.35	625	415.38	625	304.35	625	625
Row Cultivator	414.33	0	414.33	415.38	414.33	0	414.33	415.38
Sprayer	414.33	0	414.33	415.38	414.33	0	414.33	415.38

TABLE XXX (Continued)

	1989	1990	1991	1992	1993	1994	1995
Tractor	428.52	619.33	914.38	914.47	914.38	914.38	428.52
Tandum Disk	304.35	415.38	625	625	625	625	304.35
Moldboard Plow	304.35	415.38	625	625	625	625	304.35
Field Cultivator	304.35	0	210.67	209.62	210.67	210.67	304.35
Springtooth	608.70	830.76	1250	1250	1250	1250	608.70
Drill	304.35	415.38	625	625	625	625	304.35
Row Cultivator	0	415.38	414.33	415.38	414.33	414.33	0
Sprayer	0	415.38	414.33	415.38	414.33	414.33	0

* Usage given in hours for tractor and acres for implements.

Machinery Investment/Disinvestment Simulation Model with Variable Usage and Random Returns

The simulation model based on the probabilities and random number generator was ran 100 times in order to develop and examine replacement distributions. Several alternative replacement criteria are examined due to the inability of the replacement model in determining the economic optimum replacement period with stochastic returns.

A Simulation Example

Table XXXI shows one of the 100 model simulations based on random gross returns, random repair costs, and random salvage values. Column 3 shows fluctuating gross returns to machinery due to fluctuating gross returns to production. Column 4 illustrates fluctuating machinery ownership costs attributable to random repair and maintenance machinery costs and fluctuating machinery market salvage values. Column 6 gives the period net returns to machinery. Of importance is the fluctuating net returns to machinery as the variables affecting the replacement decision vary. Kletke (1969, p. 5) responds to this uncertainty of returns to machinery in his replacement study based upon cost analysis in stating, "Developing a realistic replacement model is hampered, not by whether or not machinery will be needed, but by the inability to anticipate accurately future cost and returns."

Applying the investment/disinvestment decision criteria strictly as outlined in Chapter II in this simulation results in replacing the machinery complement at the end of the third period. This is because

TABLE XXXI

A REPLACEMENT MODEL SIMULATION INCORPORATING RANDOM RETURNS TO MACHINERY

Age (1)	Returns Less Variable Cost (2)	Returns to Machinery (3)	Period Costs (4)	Present Value (5)	Period Returns (6)	Average Returns (7)
1	44953.85	11996.85	28827.07	-15583.55	-16830.23	-16830.23
2	54379.77	23293.02	5995.08	- 793.35	17297.93	- 422.45
3	41649.68	10098.62	4572.74	3633.27	5525.87	1409.83
4	33682.49	4085.63	5858.04	2330.48	- 1772.42	703.62
5	98755.00	46345.79	5054.02	30432.91	41291.66	7122.12
6	109051.00	52015.72	14484.21	54084.09	37531.41	11699.21
7	70842.00	25286.41	12266.60	61681.02	13019.80	11847.21
8	48577.41	14553.91	14090.67	61931.28	463.23	10776.96
9	87604.13	36135.36	18157.05	70924.88	17978.23	11353.64
10	96249.06	38067.76	27156.49	75989.88	10911.20	11323.09
11	98712.81	38167.63	26775.26	80864.75	11392.19	11327.23
12	56031.77	8107.03	37176.52	69320.81	-29069.50	9198.52
13	76656.00	27083.49	27934.13	69008.00	- 850.65	8731.02
14	103443.30	36225.13	41967.07	67053.06	- 5741.95	8133.32
15	77682.19	17174.04	54698.16	55223.88	-37524.13	6451.78

period returns of -1772.42 in year four (column 6) are less than the annualized average returns (colum 7) of 703.62. However, examining the annualized average returns, returns do not reach a maximum until period seven with a figure of $11847.21. This inaccuracy occurs because of the violations of the assumptions made in developing the analytical replacement model when returns to machinery are stochastic. If returns are low in an early period of the machinery's projected life, the theoretical model may replace the machinery early not accounting for the condition with stochastic returns that later returns may increase and actually increase the annualized average from that of earlier periods.

A question arises with stochastic returns incorporated into the model as to why the marginal returns (period returns) are compared to the annualized averages in column 7. Why not evaluate the annualized average directly and look for the period when the average returns are the highest? The reason this is not done is that while the model developed is a long-run model with returns projected until 1995, the machinery investment/disinvestment decision is a decision which must be made yearly. A farmer does not purchase machinery in 1981 and decide in 1981 when that machinery is going to be replaced. The decision is made each production period based on past returns to machinery and the projected returns and requirements for the following periods. Thus the comparison must be made at the end of each period n whether to keep or replace the machinery according to the projected returns the following periods.

Moving Averages of the Period Returns

A possible method for improving the forecasting accuracy of the analytical model with stochastic returns is to compute a moving average of the period (marginal) returns and compare this average to the annualized average returns. 100 simulations of the investment/ disinvestment decision model incorporating variable usage and random returns were estimated. Five replacement criteria were tested in each simulation. Along with comparing the marginal returns to the annualized average, a comparison of a three-year, four-year, five-year, and six-year moving average of period returns to the annualized average was made.

Table XXXII shows the period returns, three-year, four-year, five-year, and six-year moving average of the returns and the annualized average for one of the 100 simulations. Of interest is the way the moving averages smooth the fluctuations and delay the investment/ disinvestment decision. In this particular simulation, the marginal criterion replaces the machinery at the end of period three, the three-year moving average replaces after period eight, the four-year after period nine, the five-year after period ten, and the six-year at the end of period 11. The maximum annualized average occurs in period seven. Thus in this simulation the marginal criterion replaces four years early with a reduction in average returns of $11,143.38, the three-year moving average replaces one period later with a reduction of $1,070.25, the four-year moving average two years later with a reduction of $493.36, the five-year moving average three periods later with a reduction of $524 in average returns and the six-year moving average replaces with a reduction in annualized returns of $520. Thus the four-year moving average comes the closest in achieving the economic optimum in this example.

TABLE XXXII

COMPARISON OF REPLACEMENT CRITERIA FOR ONE SIMULATION

Year (1)	Period Returns (2)	Three-Year Moving Average of Period Returns (3)	Four-Year Moving Average of Period Returns (4)	Five-Year Moving Average of Period Returns (5)	Six-Year Moving Average of Period Returns (6)	Average Returns (7)
1	-16830.23	-	-	-	-	-16830.23
2	17297.93	-	-	-	-	- 422.45
3	5525.87	1997.86	-	-	-	1409.83
4	- 1772.42	7017.13	1055.29	-	-	703.62
5	41291.66	15015.04	15585.76	9102.56	-	7622.12
6	37351.41	25683.54	20644.11	19974.86	13840.68	11699.21
7	13019.80	30614.27	22517.59	19119.23	18815.68	11847.21
8	463.23	17004.81	23076.52	18106.72	16009.91	10776.96
9	17978.23	10487.09	17248.16	22056.85	18085.30	11353.64
10	10911.20	9784.22	10593.11	15980.76	20199.24	11323.09
11	11392.19	13427.21	10186.21	10752.93	15216.01	11327.23
12	-29069.50	- 2255.37	2803.03	2355.07	4115.86	9198.52
13	- 850.65	- 6175.98	- 1904.19	2072.29	1804.12	8731.02
14	- 5741.95	-11887.36	- 6067.48	- 2671.74	769.92	8133.32
15	-37524.13	-14705.58	-18296.55	-12358.80	-8480.46	6451.78

Results of Simulation

As stated, 100 simulations incorporating random returns and variable usage were estimated. The five replacement critera were tested in each simulation. A summary of the statistical results of the 100 simulations are as follows.

Table XXXIV in Appendix A gives the simulation number and the optimal economic life as determined by each replacement criterion. Cumulative distribution tables for each criterion are given in Figures 19 through 23. Statistical information concerning each distribution are the following.

The marginal criterion (Figure 19) based on the 100 simulations has a mean replacement period of 3.97, a median of 5.5, and a mode of 5. The standard error is 2.3288.

The three-year moving average criterion (Figure 20) results in a mean replacement of 6.79, a median of 7.5 and a mode of seven. The standard error was 2.85.

The four-year criterion produced a mean of 8.26 years, a median of 8.5 and a replacement mode of eight. The standard error was 2.6116 (Figure 21).

The five-year criterion selection (Figure 22) results in a distribution mean of 9.65 years, a median of 9.5, and a mode of nine. The standard error was estimated to be 2.524.

Concluding, the six-year moving average criterion (Figure 23) resulted in a mean, mode, and median of ten years. The standard error was 2.51.

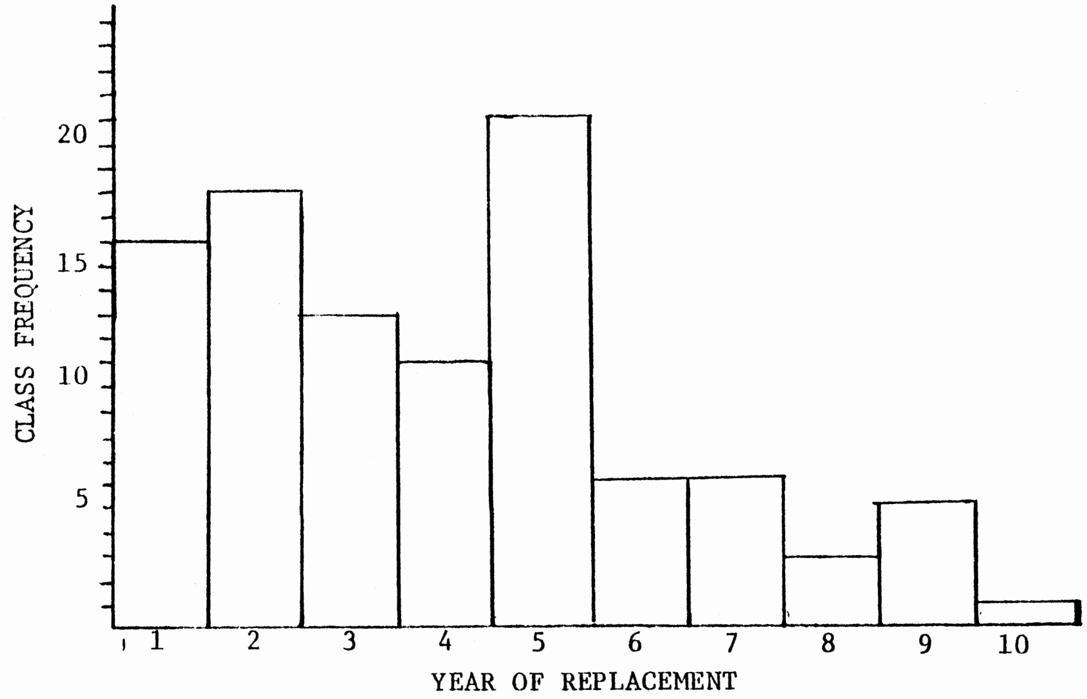


Figure 19. Histogram of 100 Replacements Using Marginal Revenue Criteria

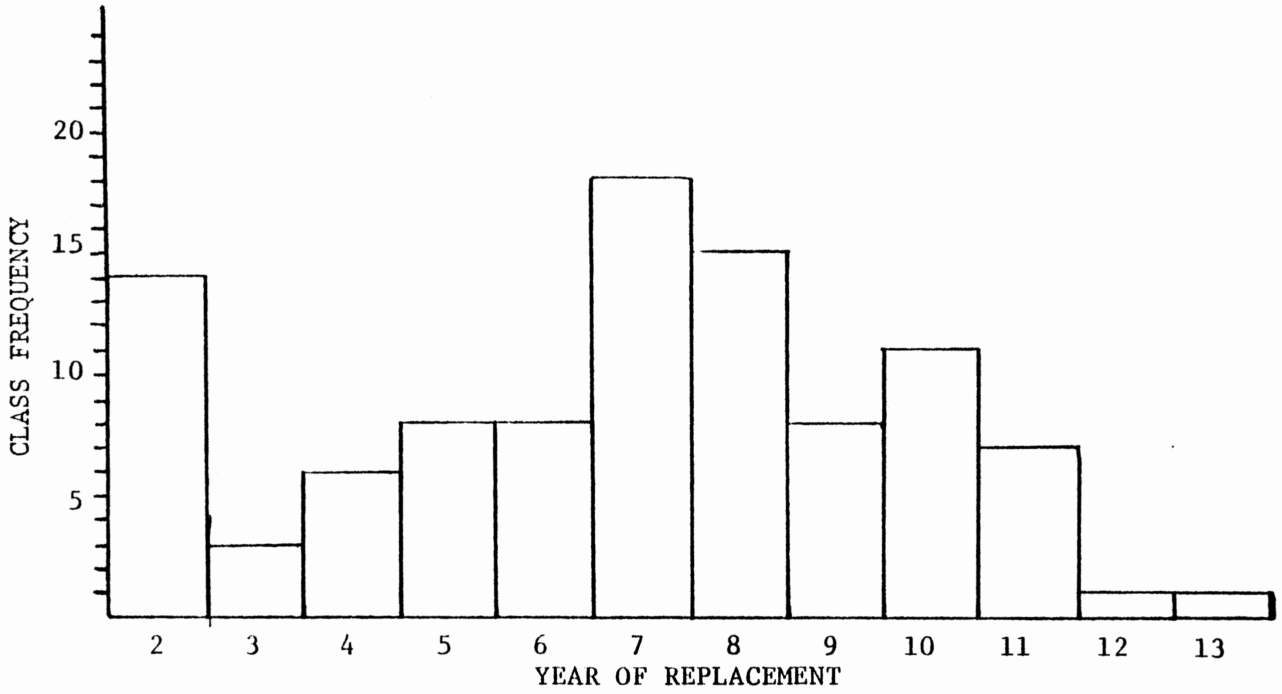


Figure 20. Histogram of 100 Replacements Using Three-Year Moving Average of Period Returns Criteria

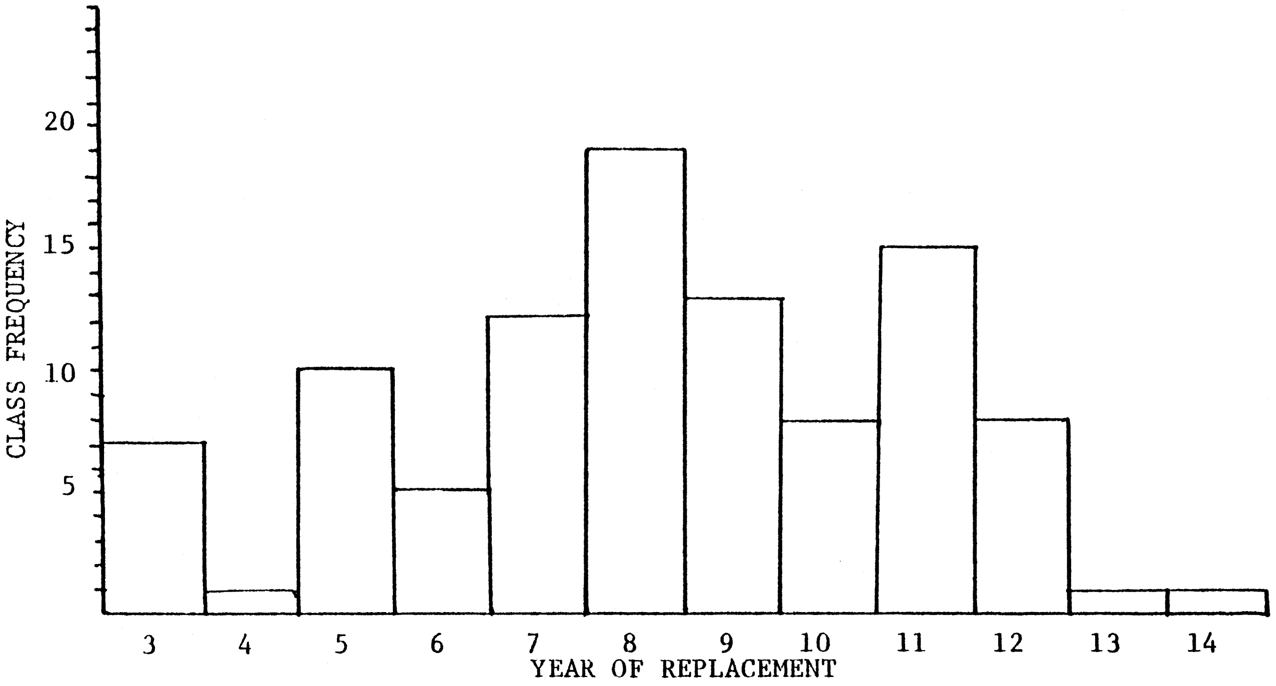
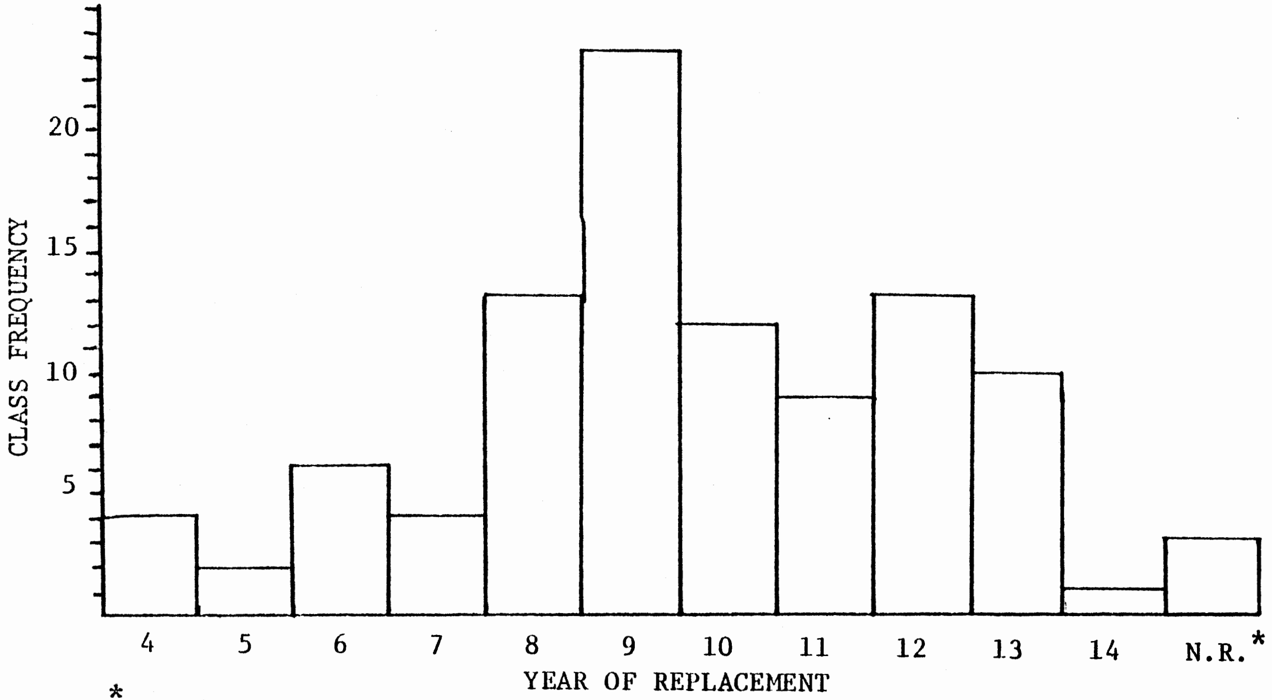
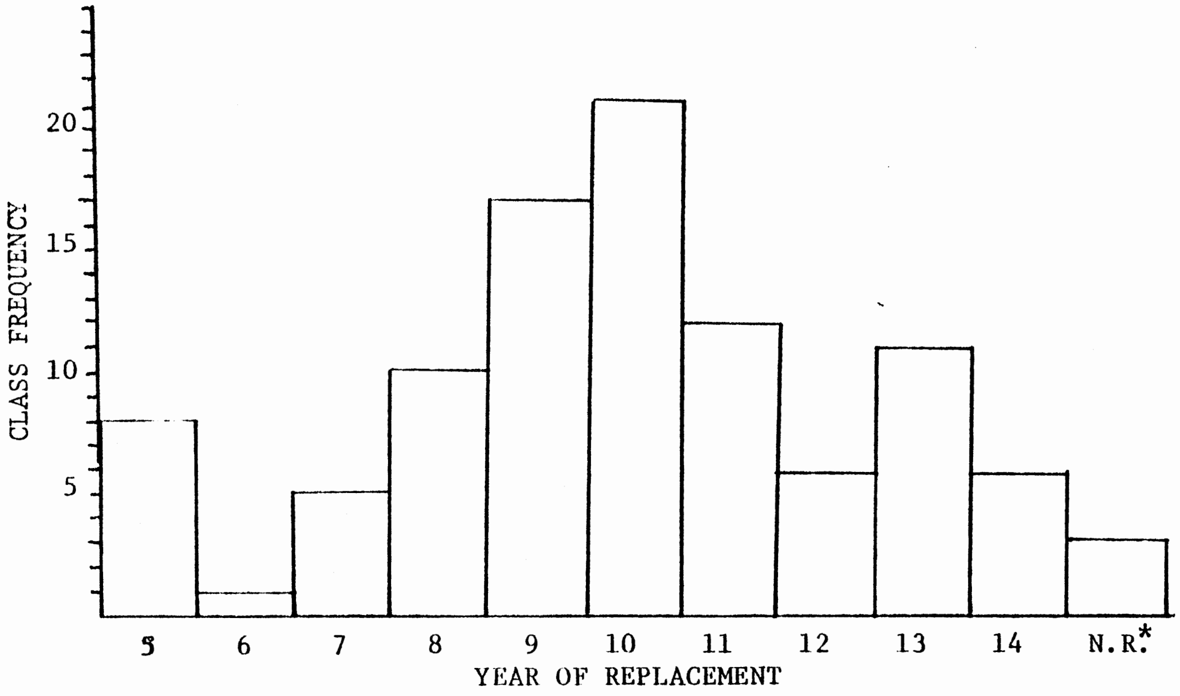


Figure 21. Histogram of 100 Replacements Using Four Year Moving Average of Period Returns Criteria



*Not replaced in 14 year planning horizon.

Figure 22. Histogram of 100 Replacements Using Five Year Moving Average Criteria



*Not Replaced in 14 year Planning horizon.

Figure 23. Histogram of 100 Replacements Using Six Year Moving Average of Period Returns Criteria

Selecting a Replacement Criterion

The procedure used in selecting the optimal replacement criterion based on the 100 simulations estimated in this study is explained below. The annualized average in the year of disposition recommended by each of the five replacement criterion was recorded for the 100 simulations. The annualized averages were summed and divided by 100 resulting in an "average" annualized return for each of the distributions discussed in the preceding section. The replacement criterion which resulted in the highest annualized average was judged to be the optimal replacement criterion with random returns.

The marginal criterion produced a total annualized average for the 100 runs of $216,818.00. Dividing the the 100 runs results in an average for the distribution of $2168.88. The three-year moving average resulting in an average of $3560.28, the four-year of $3791.74, the five-year of $3733.93 and the six-year of $3543.28. Thus using the four-year moving average of period returns criterion resulted in the highest annualized average returns in the year of replacement and is judged to be the optimal replacement criterion based on this sample. However, it should be noted that there is very little difference in lost returns from using the other moving averages and all were found to be superior to the marginal criterion in selecting the optimum replacement period with random returns to machinery.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The main objective of this study was to empirically test a durable investment/disinvestment model developed by Robison (1980). Other objectives include: (1) To project returns to machinery for a hypothetical farm in Northcentral Oklahoma for the period 1981 to 1995, (2) To incorporate the new tax regulations from the 1981 Economic Recovery Tax Act into the investment/disinvestment model, (3) To determine the effects of changes in various parameters and economic conditions on the replacement model, and (4) to analyze the effects of uncertainty on the replacement model and test several replacement criteria for determining optimal investment/disinvestment with stochastic returns.

An understanding of economic resource theory and analytical replacement models is a necessary precursor for performing sound empirical investment/disinvestment analysis. The literature review begins with a presentation of resource theory by Leftwich (1980) which ties in how the investment and production decisions made by other firms in the industry affect the market demand faced by an individual firm. Fixed asset theory by Johnson (1971) and others is critiqued next. This theory examines the acquisition and disposal of resources based on the divergence between acquisition and salvage prices. Following this is the examination of a theoretical replacement model by Faris (1960) based on net returns to machinery. The criterion for replacement of assets with revenues being realized throughout the life of the asset is when marginal net revenue from the present enterprise equals the highest amortized present value of anticipated net revenue from the following enterprise.

Baquet (1980) develops a theoretical model in which both durable assets and the flow of services from the durable are inputs in a vertically integrated production process. This allows for varying extraction rates in determining the optimal amount of services extracted from the durable in each production period.

The literature review concludes with a presentation of a classification of the costs associated with the ownership of a durable and an investment/disinvestment model by Robison (1980). Machinery ownership costs incorporated in the investment/disinvestment model include: (1) time depreciation costs which equal the change in salvage value attributable to changes in demand for the durable and/or output produced from the durable's services, (2) direct user costs which equal the change in salvage value associated with using up services of the durable, (3) control time costs which equal the change in salvage value resulting from the passage of time, and (4) control costs which represent the opportunity cost of controlling the asset. The replacement model developed by Robison used in this study assumes the economic life of future durables is identical to the first and compares marginal returns in each period to annualized average returns. The optimal economic life is the point in time when marginal returns are no longer greater than the amortized average returns.

A systems model was developed to test the investment/disinvestment decision model. A linear programming subsystem determines the optimal crop production given projected returns less variable cost/acre. After determining machinery usage each year from the linear programming subsystem and Oklahoma State Enterprise Budget guidelines, durable asset ownership costs are computed using the 1980 American Agricultural Engineer Yearbook equations and durable ownership costs guidelines explained by Robison (1980). Tax considerations for the ownership of machinery based on the 1981 Economic Recovery Tax Act are estimated in the model and returns to machinery are separated from the other fixed factors of production. The net returns to machinery for each period in the planning horizon are estimated and the optimal investment/disinvestment decision for the machinery complement is determined. The following summarizes the simulations conducted in this study. Table XXXIII presents a lising of the results of the simulations.

A hypothetical farm in Northcental Oklahoma consisting of 625 acres was used in analyzing the replacement model. Wheat and grain sorghum were the two crop alternatives. Gross returns and variable osts/acre were estimated based on 1950-1981 data with year and year squared the independent variables.

For income tax purposes the accrual method in which all items of gross income from the farming operation and farm business expenses are included in the tax year in which they are incurred, regardless of when payment is received or paid is used. A calender year represents a tax year. A farmer and his wife with two children were assumed to file a joint return in computing tax considerations. The standard depreciation period of five years under the 1981 Economic Recovery Tax Act was chosen in depreciating the machinery complement and a ten percent investment

TABLE XXXIII

SUMMARY OF REPLACEMENT MODEL SIMULATION RESULTS

Simmulation	Optimal Economic Replacement Period
Base Solution	7
Lower Returns Generated throughout projected lifetime	5
Higher Returns Generated throughout projected lifetime	8
Addition of 100 acres cropland	6
Reduction of 100 acres cropland	9
Blue Book Salvage Values	8
50 percent reduction in estimated repair and maintenance cost throughout projected lifetime	10
25 percent reduction in estimated repair and maintenance cost throughout projected lifetime	8
50 percent increase in estimated repair and maintenance cost throughout projected lifetime	5
100 percent increase in estimated repair and maintenance cost throughout projected lifetime	5
Model without tax considerations	8
Model based on old tax regulations (prior to 1981 Recovery Tax Act)	7
Model based on 1981 Economic Recovery Tax Act (Base Solution)	7
Four-year moving average of period returns criteria incorporating random returns and variable usage of machinery (100 simulations)	
a. Mean	8.26
b. Median	8.50
c. Mode	8

credit was taken in the year of acquisition of the machinery complement.

In the base solution due to the nature of the projected returns the profit-maximizing solution determined by the linear programming system for the 15 year planning horizon was 210 acres of wheat on Class I land, 39.33 acres of grain sorghum on Class I land and 375 acres of grain sorghum on Class II land. By comparing the marginal returns to the multi-period gain function (amortized average) an economic life of seven years was determined for the machinery complement.

To determine the effect of gross returns on the investment/disinvestment decision two different forecasting procedures other than that used in the base solution were incorporated into the replacement model. A forecasting procedure using 1970-81 data based on a trend model with later observations weighted heavier than earlier observations generated lower net returns to machinery throughout the planning horizon which reduced the economic life of the machinery complement to five years. A forecasting method using a simple linear regression based on 1976-81 data resulted in greater returns to machinery than the base solution. With greater net returns throughout the projected life the economic life of the machinery complement increased to eight years.

The next parameter affecting the replacement decision examined was farm size. Farm size was increased and decreased by 100 acres. A 100 acre increase in farm size decreased the economic life of the machinery to six years while a decrease of 100 acres increased the economic life to nine years. An increase in farm size decreases the economic life of the machinery complement because of the decrease in returns in later years due to the higher repair and maintenance cost attributable to increased machinery usage. A decrease in farm size has the opposite effect in that returns in later years are increased due to lower repair and maintenance cost.

Salvage values were reestimated based on 1980 Machinery Blue Book values. Although the replacement period did not change, the model illustrated how machinery appreciation may actually decrease ownership cost as the machinery ages due to zero or negative time depreciation cost.

Repair and maintenance costs are one of the largest costs associated with the ownership of farm machinery. Repair costs of 50, 75, 150, and 200 percent of those estimated in the base solution were computed and incorporated in the model to reflect the large range of possible repair costs. A 50 percent reduction in repair costs increased the economic life to ten years and a 75 percent reduction increased the economic life to eight years. An increase in repair cost of both 150 and 200 percent decreased the economic life of the machinery complement to five years.

The final sensitivity test performed was the evaluation of the effects of the 1981 Economic Recovery Tax Act on the replacement decision. Dropping taxes from the model resulted in an increase from seven to eight years in the economic life of the machinery complement. Although the 1981 Economic Recovery Tax Act increased the present value of the returns to machinery $16,416 over the model without taxes and by $1,163 over the model based on past tax regulations and tables, an economic life of seven years was determined under both tax policies. Therefore in this instance, the 1981 Economic Recovery Tax Act increased returns due to the investment of machinery; however, failed to decrease the economic life of the machinery complement and encourage increased investment.

The investment/disinvestment decision and sensitivity test discussed to this point assumed costs and returns were known with perfect knowledge. The model simulations in Chapter V incorporated variable machinery usage and random returns in the replacement decision by the use of a random number generator in order to produce probability distributions. Gross returns, repair and maintenance costs, and salvage values were allowed to vary by specifying probabilities of the prediction and generating random numbers. The simulation model based on probabilities and the random number generator was ran 100 times and several alternative replacement criteria were examined. Along with comparing the marginal returns to the annualized average the comparison of a three-year, four-year, five-year, and six-year moving average of period returns to the annualized average returns was made. Using maximum annualized average returns as a judging criterion the four-year moving average of period returns with a mean replacement period of 8.26, a median of 8.5, a mode of eight, and a standard error of 2.6 was judged to be the best replacement criterion of those tested in determining replacement with stochastic returns to machinery. However use of any of the other moving averages tested would result in very little difference in lost returns and all moving averages were judged to be superior in maximizing returns to machinery than the marginal crierion when returns to machinery are random.

Limitations and Need for Further Research

To make the durable machinery investment/disinvestment model more useful and realistic the following suggestions are made:

(1). The tractor and complements in this study were treated as a single unit when analyzing replacement. Further theoretical developments are needed to separate the gains attributable to each durable and to inputs used in conjunction with the durable.

(2). Replacement criteria assumed the machinery complement would be replaced with an identical unit with identical net returns over time. Criteria is needed in other cases such as technological improvements in the current complement or a completely different type of machinery.

(3). Further empirical investigation is needed in developing the replacement model by applying the investment/disinvestment framework to different farms, machinery, crops, etc.

(4). Better forecasting techniques need to be developed in forecasting future returns to machinery and in dealing with uncertainty. A possible area of research would be the use of Bayesian analysis in which marketing and farm management specialist could be surveyed for subjective probabilities as to future machinery costs and returns.

(5). In all simulations made in this study the linear programming subsystem determined optimal production given the predicted returns and cost for that year. Effects of non-optimal production decisions on the machinery replacement decision should be examined.

In conclusion, the empirical investment/disinvestment model developed in this study contributes to the understanding and development of durable resource theory and increases the knowledge of the interaction among costs associated with the ownership of durables and the effects of changes in various parameters on the investment/ disinvestment decision.

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APPENDIX A

OPTIMAL ECONOMIC LIFE DETERMINED BY EACH REPLACEMENT CRITERION

TABLE XXXIV

SIMULATION AND OPTIMAL ECONOMIC LIFE DETERMINED BY EACH REPLACEMENT CRITERION

Simulation Number	Marginal Returns	Three-Year Moving Average	Four-Year Moving Average	Five-Year Moving Average	Six-Year Moving Average
1	2	10	11	11	11
2	2	11	14	13	14
3	4	10	11	11	13
4	5	6	12	12	10
5	5	7	8	9	10
6	9	10	11	12	12
7	9	11	11	13	13
8	4	6	7	8	8
9	3	10	11	12	11
10	1	3	3	13	13
11	5	6	6	7	8
12	1	3	11	N.R.	N.R.
13	4	10	11	12	13
14	6	7	8	11	11
15	2	2	9	10	10
16	4	5	7	8	8
17	1	3	3	6	5
18	7	7	8	8	8
19	1	8	10	10	10
20	4	4	5	4	7
21	5	5	6	8	10
22	1	2	8	N.R.	N.R.
23	2	4	5	6	7
24	1	2	11	11	13
25	2	4	10	11	12

TABLE XXXIV (Continued)

Simulation Number	Marginal Returns	Three-Year Moving Average	Four-Year Moving Average	Five-Year Moving Average	Six-Year Moving Average
26	7	8	8	9	9
27	3	7	7	7	8
28	6	8	8	9	10
29	2	4	5	4	5
30	3	9	10	11	11
31	5	6	7	8	9
32	5	7	8	8	9
33	5	8	8	9	9
34	6	7	8	9	10
35	10	10	11	12	13
36	1	2	9	9	9
37	7	8	9	10	10
38	3	13	13	14	13
39	3	5	5	6	5
40	4	10	11	12	12
41	4	9	9	10	9
42	5	9	10	9	10
43	2	8	8	9	10
44	5	5	5	6	5
45	8	8	9	10	11
46	2	2	3	4	7
47	2	2	7	9	9
48	5	6	7	8	9
49	1	2	8	8	10
50	3	5	3	12	11

TABLE XXXIV (Continued)

Simulation Number	Marginal Returns	Three-Year Moving Average	Four-Year Moving Average	Five-Year Moving Average	Six-Year Moving Average
51	5	5	5	6	5
52	5	7	7	9	9
53	9	11	12	13	14
54	5	7	12	13	14
55	8	8	9	10	11
56	4	6	7	7	8
57	7	9	11	11	11
58	1	9	9	11	12
59	1	2	4	5	5
60	2	4	5	4	7
61	5	6	7	8	9
62	5	7	7	8	9
63	5	7	8	9	10
64	1	2	3	5	12
65	3	8	12	12	8
66	2	10	11	13	13
67	2	8	10	10	11
68	3	4	5	12	12
69	5	9	9	9	10
70	1	2	9	9	10
71	9	11	12	13	14
72	1	11	12	12	13
73	6	10	10	10	11
74	7	7	8	8	9
75	5	7	8	9	10

TABLE XXXIV (Continued)

Simulation Number	Marginal Returns	Three-Year Moving Average	Four-Year Moving Average	Five-Year Moving Average	Six-Year Moving Average
76	2	8	9	9	9
77	2	2	3	9	9
78	4	9	10	N.R.	9
79	3	7	6	9	8
80	3	10	11	13	13
81	6	7	8	9	10
82	7	8	10	10	10
83	2	2	5	12	5
84	2	2	6	6	6
85	1	2	8	9	9
86	9	11	12	13	14
87	5	7	7	9	9
88	6	7	8	9	10
89	3	5	6	7	7
90	1	12	12	13	14
91	5	11	11	11	11
92	4	6	7	8	8
93	5	7	9	9	N.R.
94	1	8	8	9	10
95	3	7	8	8	8
96	4	5	5	12	5
97	8	9	9	10	10
98	2	10	11	12	13
99	2	8	3	10	10
100	3	8	9	10	11

* N.R. implies that the economic life was not reached in the 15 year planning horizon.

APPENDIX B

LISTING OF COMPUTER PROGRAM

The investment/disinvestment Fortran Watfiv program developed for this study is shown in Table XXXIII. The model as listed is that used in generating machinery investment/disinvestment distributions based on random numbers and probabilities. Statement 15 loops the entire program the number of times specified by the programmer. Statement 97 rewinds the data file so that the program may begin another loop. If the investment program is looped the input data must be placed in a file and run using TSO.

Whether on TSO file or computer cards the input is typed using the same procedure. First the linear programming matrix must be defined as specified in the subroutine LPSUB. It is very important to define the linear programming matrix as specified by the arguements beginning with statement 212. Each A(I,J), B(K) should be typed with decimal point in a ten-column field beginning at column one. Next, gross returns/acre GRET and variable cost of production/acre VCO are inputed in according to statements 271-272. On each card or line the gross returns/acre is typed in column one through ten and variable cost/acre in columns 11 through 20. Numerals should be typed with decimal points.

The next variable to be typed is IASST, the number of assets included in the machinery complement. This variable is typed right justified without decimal point in columns one through three according to statements 31-32.

Proceeding, the next card or line contains the variables RATE, MLIFE,PNEW,TOTLF, and IEQ. RATE is the specified discount rate, MLIFE the desired length of planning horizon, PNEW the purchase price of an asset, TOTLF the estimated physical life of the asset, and IEQ the machinery engineering code. The typing specifications for these variables are given in program statement 36.

The last variable to be inputed is the machinery salvage price as specified in statements 77-78. The prices should be typed in six-column fields beginning at column one including decimal points.

The first common block of the investment routine reads in the variables inputed into the program and calls the other subroutines. The sequence is as follows: statements 16-28 initialize many of the variables setting them equal to zero. Statement 30 calls the linear programming subroutine which begins at statement 212. Subroutine LPSUB begins with directions for defining the dimensions of the linear programming matrix. Statement 269 initialized the random number generator. The random number generator RANF is a Fortran subprogram by Chandler (1972) of the Oklahoma State University Computer Science Department. This function generates pseudo-random numbers uniformily distributed on the interval (0,1). It uses the most reliable method known to generate random numbers with a computer and generally passes all known tests of randomness.

Statements 273-294 assign gross returns based on the probabilities specified and the random number generated. Statement 302 calls the ZX3LP subroutine. The ZX3LP subroutine is an IMSL Fortran subroutine which solves the linear program problem via a revised simplex algorithm. The output generated by the linear programming subroutine is Z, C(Z), PSOL(Z), and S. Respectively, these variables represent year, net returns per acre for each crop, the optimal acreage to be planted of each crop, and the value of the objective function.

Following the LPSUB routine the program returns to statement 31.

After reading in variables, statements 37-76 compute annual machinery usage based on the optimal acreage planted as determined by the LPSUB routine.

The program next calls the repair and maintenance cost subroutine. (Statement 79). Subroutine CALC begins at statement 324. Machinery repair and maintenance cost are computed based on TAR equations and IEQ codes reported in the 1980 A.S.A.E. Yearbook.

Upon the completion of calculating machinery annual usage and repair and maintenance cost for each implement, statement 94 calls the investment/disinvestment subroutine which begins at statement 101. Statements 175-178 call the appropriate tax subroutine which calculates the tax savings due to the machinery investment. The investment/disinvestment subroutine calculates net returns to machinery and outputs the necessary information to determine the optimal investment/disinvestment decision as outlined in Chapters II and III.

TABLE XXXV

INVESTMENT/DISINVESTMENT COMPUTER PROGRAM

```
$JOB
C
C     MAJOR VARIABLES
C
C     TER = INTEREST CHARGES ON MACHINERY PER PERIOD
C     TAS = TAX SAVINGS ATTRIBUTABLE TO MACHINERY INVESTMENT
C           (DOES NOT INCLUDE TAX CREDIT)
C     EXEM = TAX EXEMPTIONS $$$
C     MAN = TOTAL MANAGEMENT CHARGES
C     OVER = TOTAL OVERHEAD CHARGES
C     TPS(Z) = TAX DEPRECIATION DEDUCTIONS FOR BUSINESS PROPERTY
C     TAXCR = TAX CREDIT FOR MACHINERY INVESTMENT
C     RANF = RANDOM NUMBER GENERATOR
C     ZCON = CONTROL COST REFLECTED BY SALVAGE VALUE *
C            DISCOUNT RATE
C     TAXES = TAXES ON MACHINERY PER PERIOD
C     PRICE = SALVAGE PRICE OF ASSET
C     RPOLY = MULTI-PERIOD GAIN FUNCTION
C     PVRC = PRESENT VALUE OF SUMMATION OF RETURNS
C     ANCST = PERIOD COST OF MACHINERY COMPLIMENT
C     SUR = INSURANCE COST ON MACHINERY PER PERIOD
C     MLIFE = DESIRED LENGTH OF PLANNING HORIZON
C     PUSED = 21 X 1 ARRAY OF MKT VALUES FOR THE USED ASSET
C     PNEW = PURCHASE PRICE OF THE ASSET
C     IASST = NUMBER OF ASSETS TO BE PROCESSED PER RUN
C     VRUSE = 21X1 ARRAY USED TO REFLECT VARYING USE SALVAGE VALUES
C     VCOST = 21X1 ARRAY USED TO REFLECT VARYING USE OPERATING COSTS
C     RGRO = GROSS RETURNS TO MACHINERY
C     RNET = NET RETURNS TO MACHINERY
C     RTRN = GROSS RETURNS
C     RATE = DISCOUNT RATE
C     LAND(I) = RETURNS ALLOCATED TO LAND
C     MAN(I) = RETURNS CHARGED TO MANAGEMENT
C     OVER(I) = RETURNS CHARGED TO OVERHEAD
C     LPSUB = FORTRAN LINEAR PROGRAMMING SUBROUTINE
C     ZXZ = TOTAL OVERHEAD, MANAGEMENT, LAND CHARGES
C     TOTLF = ESTIMATED TOTAL HOURS OF PHYSICAL LIFE OF ASSET
C     IEQ = AGRICULTURAL ENGINEER MACHINERY CODE
C     ANUSE(I) = ANNUAL USAGE(HOURS FOR TRACTORS, ACRES FOR
C                OTHER MACHINERY)
C     OV = $9.00, 1981 OVERHEAD CHARGE FOR N.C. OKLAHOMA
C     FNI = ANNUAL PROJECTED INFLATION RATE FOR OVERHEAD CHARGES
C     YYY = TOTAL TAXES,INSURANCE,INTEREST, AND ACQUITITION COST
C           FOR A GIVEN YEAR
C        YEAR.
C     CLAI = TOTAL ACRES OF CLASS I LAND
C     CLAII = TOTAL ACRES OF CLASS II LAND
C     TAC = TOTAL PLANTABLE ACRES
C     GRET = GROSS RETURNS (PRICE * YIELD)/ACRE
C     VCO = VARIABLE COST OF PRODUCTION/ACRE
C     GRE(Z) = TOTAL GROSS RETURNS
C     VC(Z) = TOTAL VARIABLE COST
C     C(L) = NET RETURNS OF FARM.
C     TAP(Z) = OPTIMAL TOTAL PLANTED ACRES/YEAR.
C     TWP(Z) = OPTIMAL TOTAL WHEAT ACRES/YEAR.
C     TSP(Z) = OPTIMAL TOTAL GRAIN SORGHUM ACRES/YEAR.
C
      COMMON MLIFE,RATE,PTPT(21),COST(21),PUSED(21),PNEW
      COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
```

TABLE XXXV (Continued)

```
      COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
      COMMON GRET,VCO,GRE(21),VC(21),TAC
      COMMON LAND(21),MAN(21)
      COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),HOLD(21)
      COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
      COMMON TPE(21),TIN,TEN,EXEM
      COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
      COMMON TAS,TA,PA
      COMMON TAXCR(21)
      INTEGER G
      REAL A
      DO 6437 G=1,2
C
      DO 5 I=1,21
      RTRN(I) = 0.0
         PRICE(I) = 0.0
         PUSED(I) = 0.0
         VRUSE(I) = 0.0
         VCOST(I) = 0.0
      TSR(I) = 0.0
      SAL(I) = 0.0
      LAND(I) = 0.0
      MAN(I) = 0.0
      TPE(I) = 0.0
      TAXCR(I) = 0.0
    5 CONTINUE
      DLIST = 0.0
      CALL LPSUB
C
      READ(9,1000)IASST
 1000 FORMAT(I3)
C
C     INPUT THE FIRST 20 PRODUCTION PERIOD DATA
C
      DO 10 N=1,IASST
      READ(9,2000)RATE,MLIFE,PNEW,TOTLF,IEQ
      DLIST = DLIST + PNEW
 2000 FORMAT(F5.2,3X,I2,5X,2F10.2,3X,I2)
      IF(IEQ.EQ.2)GO TO 17
      IF(IEQ.EQ.4)GO TO 37
      IF(IEQ.EQ.5)GO TO 47
      IF(IEQ.EQ.6)GO TO 57
      IF(IEQ.EQ.7)GO TO 67
      IF(IEQ.EQ.8)GO TO 77
      IF(IEQ.EQ.9)GO TO 87
   17 DO 14 I=1,MLIFE
      ANUSE(I) = TRAC(I)
   14 CONTINUE
      GO TO 777
   37 DO 34 I=1,MLIFE
      ANUSE(I) = HOLD(I)
   34 CONTINUE
      GO TO 777
   47 IF(PNEW.EQ.3500)GO TO 27
      DO 44 I=1,MLIFE
      ANUSE(I) = TAND(I)
   44 CONTINUE
      GO TO 777
   27 DO 24 I=1,MLIFE
      ANUSE(I) = SPRIN(I)
```

TABLE XXXV (Continued)

```
   24 CONTINUE
      GO TO 777
   57 DO 54 I=1,MLIFE
      ANUSE(I) = FIEC(I)
   54 CONTINUE
      GO TO 777
   67 DO 64 I=1,MLIFE
      ANUSE(I) = RILL(I)
   64 CONTINUE
      GO TO 777
   77 DO 74 I=1,MLIFE
      ANUSE(I) = RCUL(I)
   74 CONTINUE
      GO TO 777
   87 DO 84 I=1,MLIFE
      ANUSE(I) = SPRA(I)
   84 CONTINUE
      GO TO 777
  777 READ(9,3000)(PRICE(K),K=1,MLIFE)
 3000 FORMAT(10F6.2)
C
C     CALL VARIABLE COST CALCULATING SUBROUTINE
C
      CALL CALC
C
      DO 10 J=1,21
         VCOST(J) = VCOST(J) + TCOST(J)
         VRUSE(J) = VRUSE(J) + PRICE(J)
C
   10 CONTINUE
      DO 931 J=1,21
      A = RANF(0)
      IF(A.LE..04) VCOST(J) = VCOST(J) * .83
      IF(A.GT..04.AND.A.LE..28) VCOST(J)=VCOST(J)*.91
      IF(A.GT..72.AND.A.LE..96) VCOST(J)=VCOST(J)*1.08
      IF(A.GT..96) VCOST(J) = VCOST(J) * 1.17
      A = RANF(0)
      IF(A.LE..3) VRUSE(J) = VRUSE(J) * .9
      IF(A.GT..7) VRUSE(J) = VRUSE(J) * 1.1
  931 CONTINUE
C
C
C
C
C     CALL SUBROUTINE FOR VARIABLE USEAGE PER PERIOD OPTIMIZATION
C
      CALL VUSE
      WRITE(6,3500)
 3500 FORMAT(1H1)
      REWIND 9
 6437 CONTINUE
      STOP
      END
C     ********************************************************************

      SUBROUTINE VUSE
C
C     VUSE SUBROUTINE OPTIMIZES ASSET INVESTMENT FOR VARYING USE EACH
C     PRODUCTION PERIOD
C
```

TABLE XXXV (Coninued)

```
      COMMON MLIFE,RATE,RTEN(21),COST(21),PUSED(21),PNEW
      COMMON YRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
      COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
      COMMON GRET,VCO,GRE(21),VC(21),TAC
      COMMON LAND(21),MAN(21)
      COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),MOLD(21)
      COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
      COMMON TPE(21),TIN,TEN,EXEM
      COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
      COMMON TAS,TA,PA
      COMMON TAXCR(21)
      REAL OV
      REAL FNI
      REAL RGRO
      REAL ZCON(21)
      REAL RNOT(21),RNAT(21)
      INTEGER G
C
C     INITIALIZE VARIABLES FOR BEGINNING OF OPTIMIZATION PROCESS
C
C     TCHNG IS THE CHANGE IN ASSET VALUE PER PRODUCTION PERIOD
C     RCOMB = DUMMY VARIABLE FOR CONTINUOS ANALYSIS COMPARISON
C
      WWW = DLIST
      DO 70 N = 1,3
      TER(N) = .163 * WWW
      WWW = WWW - (.33 * WWW)
   70 CONTINUE
      ZCON(1) = DLIST * RATE
      DO 8487 G=2,MLIFE
      ZCON(G) = VRUSE(G-1) * RATE
 8487 CONTINUE
      TAXES = .01 * DLIST
      TCHNG = DLIST
      OV = 9.00
      RCOMB = -1000000000.0
      TCOST = 0
      ABC = DLIST
      TCHNG = DLIST
      FNI = 1.07
      TAXCR(1) = .1 * DLIST
      QA = 11900.
      PB = 15000.
      PC = 20200.
      PD = 24600.
      PE = 29900.
      PF = 35200.
      PG = 45800.
      PH = 60000.
      PI = 85600.
      PJ = 109400.
      TPE(1) = .15 * DLIST
      TPE(2) = .22 * DLIST
      TPE(3) = .21 * DLIST
      TPE(4) = .21 * DLIST
      TPE(5) = .21 * DLIST
      EXEM = 5000.
      RNAT(1) = 999999999999.
      RNAT(2) = 999999999999.
```

TABLE XXXV (Continued)

```
      WRITE(6,8000)
 8000 FORMAT(1H1)
      WRITE(6,9000)
 9000 FORMAT('-',T42,'ROBISON DURABLE DISINVESTMENT ANALYSIS',///' ',
     1T2,'AGE',T11,'RETURNS LESS',T26,'RETURNS TO',T40,'PERIOD',T52,'
     2SENT',T68,'PERIOD RETURNS',T89,'MOVING AVERAGE',T105,'MULTI PERI
     3D',/' ',T2,'(A)',T11,'VARIABLE COST',T26,'MACHINERY',T40,'COSTS'
     452,'VALUE',T68,'G(S)',T89,'OF RETURNS',T105,
     5'GAIN FUNCTION',/' ',T5,115('-'))
C
C     BEGINNING OF OPTIMIZATION LOOP
C
      DSNET = 0.0
      DO 20 K=1,MLIFE
      LTOT = K
C
C         BEGINNING OF LOOP TO DISCOUNT NET RETURNS
C
      SUR = .006 * VRUSE(K)
      YYY = TER(K) + SUR + TAXES
      OVER = OV * TAC
      MAN(K) = .1 * (OVER + VC(K) + YYY)
      LAND(K) = (.3333 * GRE(K)) - (.1386 * VC(K))
      ZXZ = OVER + MAN(K) + LAND(K)
      OV = OV * FNI
         ABC = ABC - VRUSE(K)
         RNET = RTRN(K) - VCOST(K)
      RNET = RNET - YYY
      TIN = RNET - EXEM
      TEN = RNET - EXEM - TPE(K)
      IF(K.EQ.1) CALL TAX1
      IF(K.EQ.2) CALL TAX2
      IF(K.EQ.3) CALL TAX3
      IF(K.GE.4) CALL TAX4
      TAS = TA - PA
      RGRO = RTRN(K) - ZXZ
      RNET = RNET + TAS
      RNET = RNET + TAXCP(K)
      RNET = RNET - ZCON(K)
      RNET = RNET - ABC
      RNET = RNET - ZXZ
      RNOT(K) = RNET
      IF(K.LE.2) GO TO 8392
      RNAT(K) = (RNOT(K) + RNOT(K-1) + RNOT(K-2))/3.0
 8392 DSCNT = RNET/(1.0 + RATE)** K
          DSNET = DSNET + DSCNT
         ABC = VRUSE(K)
C
      TCHNG = TCHNG - VRUSE(K)
      ANCST = TCOST(K) + TCHNG + YYY + ZCON(K)
      ANCST = ANCST - TAS - TAXCP(K)
      TCHNG = VRUSE(K)
C
C     PVRC = PRESENT VALUE OF THE REPLACEMENT CYCLE
C
      PVRC = DSNET
      RK = FLOAT(K)
      RK = 0.0 - RK
C
C     RPCLY = CONTINUOS REPLACEMENT DECISION VALUE
```

TABLE XXXV (Continued)

```
C
      RPOLY = RATE * PVRC / (1 - (1 + RATE) ** RK)
C
C
C
      WRITE(6,9250)K,RTRN(K),RGRO,ANCST,PVRC,RNET,RNAT(K),RPOLY
 9250 FORMAT('0',T2,I2,T11,F10.2,T26,F8.2,T36,F12.2,T52,F9.2,T68,F9.2,
     19,F10.2,T105,F10.2)
   20 CONTINUE
      WRITE(6,9375)
 9375 FORMAT('-',T5,115('-'))
      QRATE = RATE * 100.0
      WRITE(6,9750) QRATE
 9750 FORMAT('-',T42,'DISCOUNT RATE',3X,F5.2,3X,'PERCENT')
      WRITE(6,7)DLIST
    7 FORMAT(F10.2)
      RETURN
      END
C     ******************************************************************

      SUBROUTINE LPSUB
C     ZX3LP =  IMSL LINEAR PROGRAMMING SUBROUTINE
C
C     **********IMPORTANT TO DEFINE LP MATRIX AS SPECIFIED ***********
C      ************** BY THE FOLLOWING ARGUEMENTS. ******************
C     LINEAR PROGRAMMING ARGUEMENTS LISTED BELOW:
C        A  =  MATRIX OF DIMENSION M1+M2+2 BY N CONTAINING THE
C              COEFFICIENTS OF THE M1 INEQUALITY CONSTRAINTS
C              IN THE FIRST M1 ROWS FOLLOWED BY THE
C              COEFFICIENTS OF THE M2 EQUALITY CONSTRAINTS.
C              (INPUT)  THE LAST TWO ROWS OF A ARE USED
C              ONLY AS WORKING STORAGE.
C
C
C        IA = ROW DIMENSION OF MATRIX A EXACTLY AS SPECIFIED IN
C             THE DIMENSION STATEMENT IN THE CALLING PROGRAM
C             (INPUT)  TWO ROWS OF A ARE REQUIRED FOR
C             WORKING STORAGE, AND THEREFORE, IA MUST
C             NOT BE LESS THAN M1+M2+2.
C
C
C        B = VECTOR OF LENGTH M1+M2+2 CONTAINING THE RIGHT HAND
C            SIDES OF THE INEQUALITY CONSTRAINTS IN ITS
C            FIRST M1 LOCATIONS FOLLOWED BY THE M2 RIGHT
C            HAND SIDES OF THE EQUALITY CONSTRAINTS.
C            (INPUT)  THE LAST TWO ELEMENTS OF B ARE USED
C            AS WORKING STORAGE.
C
C
C        C = VECTOR OF LENGTH N CONTAINING THE COEFFICIENTS OF THE
C            OBJECTIVE FUNCTION.  (INPUT)
C
C
C        N = NUMBER OF UNKNOWNS IN THE MODEL.  (INPUT)
C
C
C        M1 = NUMBER OF INEQUALITY CONSTRAINTS.  (INPUT)
C
C
C        M2 = NUMBER OF EQUALITY CONSTRAINTS. (INPUT)
```

TABLE XXXV (Continued)

```
C
C
C          S = VALUE OF THE OBJECTIVE FUNCTION.  (OUTPUT)
C
C
C          PSOL = VECTOR OF LENGTH N CONTAINING THE PRIMAL SOLUTION.
C                 (OUTPUT) PSOL IS ALSO USED AS WORK STORAGE
C                 AND THEREFORE MUST HAVE LENGTH AT LEAST
C                 MAX(N,M1+M2).
C
C
C          DSOL = VECTOR OF LENGTH M1+M2+2 CONTAINING THE DUAL SOLUTION.
C               (OUTPUT)
C
C
C          RW = WORK VECTOR OF LENGTH (M1+M2+2) * (M1+M2+2) + 3*M1+2*M2+
C
C
C          IW = WORK VECTOR OF LENGTH 2*M2+3*M1+4.
C
C
C          IER = ERROR INDICATOR.  (OUTPUT)
C               IER = 130 INDICATES THAT IA IS LESS THAN M1+M2+2.
C
C               IER = 131 INDICATES THAT THE COST CRITERION HAS UNBOUNDE
C
C               IER = 132 INDICATES THAT THE MAXIMUM NUMBER OF ITERATIO
C                    REACHED IN ZXOLP SUBSYSTEM.
C
C               IER = 133 INDICATES THAT NO FEASIBLE SOLUTION EXISTS.
C
C               IER = 70 INDICATES THAT SOME ARTIFICIAL VARIABLES REMAI
C                    IN THE SOLUTION BASIS AT A ZERO LEVEL AFTER PHASE
C                    THIS CONDITION CAN BE CAUSED BY HAVING REDUNDANT
C                    CONSTRAINTS.  NEVERTHELESS, A SOLUTION IS COMPUTED
C                    AND RETURNED IN PSOL AND DSOL.
        COMMON MLIFE,RATE,RTSN(21),COST(21),PUSED(21),PNEW
        COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
        COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
        COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
        COMMON GRET,VCO,GRE(21),VC(21),TAC
        COMMON LAND(21),MAN(21)
        COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),MOLD(21)
        COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
        COMMON TPE(21),TIN,TEN,EXEM
        COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
        COMMON TAS,TA,PA
        COMMON TAXCR(21)
        INTEGER IA,N,M1,M2,IW(90),IER,I,J,K,L,Z
        INTEGER CO
        REAL A(13,4),B(13),C(4),S,PSOL(11),DSOL(13),RW(225)
        REAL GRET,VCO
        REAL RGO(4),VOC(4)
        REAL JO
        N = 4
        M1 = 11
        M2 = 0
        CO = M1 + M2
        IA = 13
        I = 1
```

TABLE XXXV (Continued)

```
  107 CONTINUE
      J = 1
  108 CONTINUE
       READ(9,4071)A(I,J)
 4071 FORMAT(F10.2)
      J = J+1
      IF(J.LE.N) GO TO 108
      I = I+1
      IF (I.LE.CO) GO TO 107
      K = 1
  109 CONTINUE
      READ(9,4072)B(K)
 4072 FORMAT(F10.2)
      K = K+1
      IF (K.LE.CO) GO TO 109
      CLAI = B(1)
      CLAII = B(2)
      TAC = CLAI + CLAII
      WRITE(6,833)
  833 FORMAT(1H1)
      WRITE(6,8322)
 8322 FORMAT('-',T5,115('*'))
      WRITE(6,844)
  844 FORMAT('-',T42,'LINEAR PROGRAM OUTPUT',///' ',T15,'LEFT-HAND SI
     1COEFICIENTS OF THE CONSTRAINTS',T63,'RIGHT HAND SIDE CF CONSTRA
     2')
      DO 36 I = 1, CO
      WRITE(6,857) A(I,1), A(I,2), A(I,3), A(I,4), B(I)
  857 FORMAT(' ',T17,F5.2,T27,F5.2,T37,F5.2,T47,F5.2,T67,F8.2)
   36 CONTINUE
      WRITE(6,858)
  858 FORMAT('0',T17,'NET RETURNS PER ACRE',T60,'ACRES PLANTED',T116,'
     1T PROFIT',//' ',T11,'YEAR',T22,'CROP 1',T32,'CROP 2',T42,'CROP
     2T52,'CROP 4',T62,'CROP 1',T72,'CROP 2',T82,'CROP 3',T92,'CROP 4'
     3116,'$$$$.$$')
      DO 366 Z=1,15
      L = 1
  112 JO=RANF(0)
  111 CONTINUE
      READ(9,2540) GRET,VCO
 2540 FORMAT(2F10.2)
      IF(L.GT.2) GO TO 7469
      IF(JO.LE..003) GRET = GRET * 0.0
      IF(JO.GT..003.AND.JO.LE..018) GRET=GRET*.2
      IF(JO.GT..018.AND.JO.LE..067) GRET=GRET*.4
      IF(JO.GT..067.AND.JO.LE..184) GRET=GRET*.6
      IF(JO.GT..184.AND.JO.LE..382) GRET=GRET*.8
      IF(JO.GT..618.AND.JO.LE..816) GRET=GRET*1.2
      IF(JO.GT..816.AND.JO.LE..933) GRET=GRET*1.4
      IF(JO.GT..933.AND.JO.LE..982) GRET=GRET*1.6
      IF(JO.GT..982.AND.JO.LE..997) GRET=GRET*1.8
      IF(JO.GT..997.AND.JO.LE.1.0) GRET=GRET*2.0
      GO TO 7463
 7469 IF(JO.LE..004) GRET = GRET * .1
      IF(JO.GT..004.AND.JO.LE..022) GRET=GRET*.28
      IF(JO.GT..022.AND.JO.LE..078) GRET=GRET*.46
      IF(JO.GT..078.AND.JO.LE..198) GRET=GRET*.64
      IF(JO.GT..198.AND.JO.LE..39) GRET=GRET*.82
      IF(JO.GT..61.AND.JO.LE..802) GRET=GRET*1.18
      IF(JO.GT..802.AND.JO.LE..922) GRET=GRET*1.36
```

TABLE XXXV (Continued)

```
      IF(JO.GT..922.AND.JO.LE..978) GRET=GRET*1.54
      IF(JO.GT..978.AND.JO.LE..996) GRET=GRET*1.72
      IF(JO.GT..996.AND.JO.LE.1.0) GRET=GRET*1.9
 7463 RGO(L) = GRET
      VOC(L) = VCO
      C(L) = GRET - VCO
      L = L+1
      IF (L.EQ.2) GO TO 111
      IF (L.EQ.3) GO TO 112
      IF (L.EQ.4) GO TO 111
      CALL ZX3LP (A,IA,B,C,N,M1,M2,S,PSOL,DSOL,RW,IW,IER)
      WRITE(6,861) Z,C(1),C(2),C(3),C(4),PSOL(1),PSOL(2),PSOL(3),PSOL(
     1,S
  861 FORMAT(' ',T12,I2,T21,F7.2,T31,F7.2,T41,F7.2,T51,F7.2,T61,F7.2,T
     1,F7.2,T81,F7.2,T91,F7.2,T116,F10.2)
      RTRN(Z) = S
      GRE(Z) = (RGO(1) * PSOL(1)) + (RGO(2) * PSOL(2)) + (RGO(3) * PSC
     13)) + (RGO(4) * PSOL(4))
      VC(Z) = (VOC(1) * PSOL(1)) + (VOC(2) * PSOL(2)) + (VOC(3) * PSOL
     1)) + (VOC(4) * PSOL(4))
      TAP(Z) = PSOL(1) + PSOL(2) + PSOL(3) + PSOL(4)
      TSP(Z) = PSOL(3) + PSOL(4)
      TWP(Z) = PSOL(1) + PSOL(2)
      TRAC(Z) = (4.408 * TWP(Z)) + (1.491 * TSP(Z))
      RCUL(Z) = TSP(Z)
      SPRA(Z) = TSP(Z)
      RILL(Z) = TAP(Z)
      SPRIN(Z) = 2.0 * TAP(Z)
      FIEC(Z) = TWP(Z)
      MOLD(Z) = TAP(Z)
      TAND(Z) = TAP(Z)
  366 CONTINUE
      WRITE(6,8422)
 8422 FORMAT('-',T5,115('*'))
      RETURN
      END
C     *****************************************************************

      SUBROUTINE CALC
C     CALC SUBROUTINE CALCULATES COSTS FOR EACH ASSET
      REAL JLK(21),INF
      REAL A
C
      COMMON MLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
      COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
      COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
      COMMON GRET,VCO,GRE(21),VC(21),TAC
      COMMON LAND(21),MAN(21)
      COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),MOLD(21)
      COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
      COMMON TPE(21),TIN,TEM,EXEM
      COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
      COMMON TAS,TA,PA
      COMMON TAXCR(21)
      DO 5 I=1,21
         TCOST(I) = 0.0
      JLK(I) = 0.0
    5 CONTINUE
C
```

TABLE XXXV (Continued)

```
C     INITIALIZE SUMMATION OF USE VARIABLE
C
      USE = 0.0
      WXY = 1.0
      INF = 1.07
C
      USE =  USE + ANUSE(1)
C
C
      IF(IEQ.EQ.2)GO TO 30
      IF(IEQ.EQ.3)GO TO 40
      IF(IEQ.EQ.4)GO TO 50
      IF(IEQ.EQ.5)GO TO 60
      IF(IEQ.EQ.6)GO TO 70
      IF(IEQ.EQ.7)GO TO 80
      IF(IEQ.EQ.8)GO TO 90
      IF(IEQ.EQ.9)GO TO 100
C
C     MIDWEST COST EQUATION FOR GAS TRACTOR
      TAR = 0.0183 * ((USE / 1000.0 ) **2.159)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 10 I=2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0183 * ((USE / 1000.0 ) **2.159)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   10 CONTINUE
      RETURN
C     MIDWEST COST EQUATION FOR DIESEL TRACTOR
   30 TAR = 0.0120 * (( USE / 1000) **2.033)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 35 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0120 * (( USE / 1000) **2.033)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   35 CONTINUE
      RETURN
C     MIDWEST COST EQUATION FOR LPG TRACTOR
   40 TAR = 0.0131 * ((USE / 1000.0) **2.122)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 45 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0131 * ((USE / 1000.0) **2.122)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   45 CONTINUE
      RETURN
```

TABLE XXXV (Continued)

```
C     MIDWEST COST EQUATION FOR MOLD.PLOWS
   50 TAR = 0.0700 * ((USE / 1000.0) ** 1.810)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 55 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0700 * ((USE / 1000.0) ** 1.810)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   55 CONTINUE
      RETURN
C     MIDWEST COST EQUATION FOR DISK HARROWS
   60 TAR = 0.0025 * (( USE / 1000.0) ** 1.714)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 65 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0025 * (( USE / 1000.0) ** 1.714)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   65 CONTINUE
      RETURN
C     MIDWEST COST EQUATION FOR FIELD CULTIVATORS
   70 TAR = 0.0103 * ((USE / 1000.0) ** 1.400)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 75 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0103 * ((USE / 1000.0) ** 1.400)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   75 CONTINUE
      RETURN
C     MIDWEST COST EQUATION FOR GRAIN DRILLS
   80 TAR = 0.0359 * (( USE / 1000.0) ** 2.626)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
      TCOST(1) = TCOST(1) * WXY
      DO 85 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.0359 * (( USE / 1000.0) ** 2.626)
      JLK(I) = TAR * PNEW
      TCOST(I) = JLK(I) - JLK(I-1)
      TCOST(I) = TCOST(I) * (INF **I)
      TCOST(I) = TCOST(I) * WXY
   85 CONTINUE
      RETURN
C     MIDWEST COST EQUATION FOR ROW CULTIVATORS
   90 TAR = 0.0094 * (( USE / 1000.0) ** 2.207)
      JLK(1) = TAR * PNEW
      TCOST(1) = JLK(1) * INF
```

TABLE XXXV (Continued)

```
          TCOST(1) = TCOST(1) * WXY
          DO 95 I = 2,MLIFE
          USE = USE + ANUSE(I)
          TAR = 0.0094 * (( USE / 1000.0) ** 2.207)
          JLK(I) = TAR * PNEW
          TCOST(I) = JLK(I) - JLK(I-1)
          TCOST(I) = TCOST(I) * (INF **I)
          TCOST(I) = TCOST(I) * WXY
       95 CONTINUE
          RETURN
C         NATIONWIDE COST EQUATION FOR MOUNTED SPRAYERS
      100 TAR = 0.0499 * ((USE / 1000.0) ** 1.4)
          JLK(1) = TAR * PNEW
          TCOST(1) = JLK(1) * INF
          TCOST(1) = TCOST(1) * WXY
          DO 105 I = 2,MLIFE
          USE = USE + ANUSE(I)
          TAR = 0.0499 * ((USE / 1000.0) ** 1.4)
          JLK(I) = TAR * PNEW
          TCOST(I) = JLK(I) - JLK(I-1)
          TCOST(I) = TCOST(I) * (INF **I)
          TCOST(I) = TCOST(I) * WXY
      105 CONTINUE
          RETURN
          END
C         ****************************************************************

          SUBROUTINE TAX1
          COMMON MLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
          COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
          COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
          COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
          COMMON GRET,VCO,GRE(21),VC(21),TAC
          COMMON LAND(21),MAN(21)
          COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),HOLD(21)
          COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
          COMMON TPE(21),TIN,TEN,TXEM
          COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
          COMMON TAS,TA,PA
          COMMON TAXCR(21)
          IF(TIN.LE.0.) GO TO 49
          IF(TIN.LT.QA.AND.TIN.GT.0.) GO TO 51
          IF(TIN.LT.PB.AND.TIN.GE.QA) GO TO 52
          IF(TIN.LT.PC.AND.TIN.GE.PB) GO TO 53
          IF(TIN.LT.PD.AND.TIN.GE.PC) GO TO 54
          IF(TIN.LT.PE.AND.TIN.GE.PD) GO TO 55
          IF(TIN.LT.PF.AND.TIN.GE.PE) GO TO 56
          IF(TIN.LT.PF.AND.TIN.GE.PF) GO TO 57
          IF(TIN.LT.PH.AND.TIN.GE.PG) GO TO 58
          IF(TIN.LT.PI.AND.TIN.GE.PH) GO TO 59
          IF(TIN.LT.PJ.AND.TIN.GE.PI) GO TO 60
          IF(TIN.GE.PJ) GO TO 61
       49 TA = 0.0
          GO TO 67
       51 TA = TIN * .1
          GO TO 67
       52 TA = 1104. + (.21 * (TIN - QA))
          GO TO 57
       53 TA = 2265. + (.24 * (TIN - PB))
          GO TO 67
```

TABLE XXXV (Continued)

```
   54 TA = 3273. + (.28 * (TIN - PC))
      GO TO 67
   55 TA = 4505. + (.32 * (TIN - PD))
      GO TO 67
   56 TA = 6201. + (.37 * (TIN - PE))
      GO TO 67
   57 TA = 8162. + (.43 * (TIN - PF))
      GO TO 67
   58 TA = 12720. + (.49 * (TIN - PG))
      GO TO 67
   59 TA = 19678. + (.54 * (TIN - PH))
      GO TO 67
   60 TA = 33502. + (.59 * (TIN - PI))
      GO TO 67
   61 TA = 47544. + (.64 * (TIN - PJ))
      GO TO 67
   67 IF(TEN.LE.0.) GO TO 19
      IF(TEN.LT.QA.AND.TEN.GT.0.) GO TO 20
      IF(TEN.LT.PB.AND.TEN.GE.QA) GO TO 21
      IF(TEN.LT.PC.AND.TEN.GE.PB) GO TO 22
      IF(TEN.LT.PD.AND.TEN.GE.PC) GO TO 23
      IF(TEN.LT.PE.AND.TEN.GE.PD) GO TO 24
      IF(TEN.LT.PF.AND.TEN.GE.PE) GO TO 25
      IF(TEN.LT.PG.AND.TEN.GE.PF) GO TO 26
      IF(TEN.LT.PH.AND.TEN.GE.PG) GO TO 27
      IF(TEN.LT.PI.AND.TEN.GE.PH) GO TO 28
      IF(TEN.LT.PJ.AND.TEN.GE.PI) GO TO 29
      IF(TEN.GE.PJ) GO TO 30
   19 PA = 0.0
      RETURN
   20 PA = TEN * .1
      RETURN
   21 PA = 1404. + (.21 * (TEN - QA))
      RETURN
   22 PA = 2265. + (.24 * (TEN - PB))
      RETURN
   23 PA = 3273. + (.28 * (TEN - PC))
      RETURN
   24 PA = 4505. + (.32 * (TEN - PD))
      RETURN
   25 PA = 6201. + (.37 * (TEN - PE))
      RETURN
   26 PA = 8162. + (.43 * (TEN - PF))
      RETURN
   27 PA = 12720. + (.49 * (TEN - PG))
      RETURN
   28 PA = 19678. + (.54 * (TEN - PH))
      RETURN
   29 PA = 33502. + (.59 * (TEN - PI))
      RETURN
   30 PA = 47544. + (.64 * (TEN - PJ))
      RETURN
      END
C     ***************************************************************

      SUBROUTINE TAX2
      COMMON MLIFE,RATE,RTPY(21),COST(21),PUSED(21),PNEW
      COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
      COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
```

TABLE XXXV (Continued)

```
      COMMON GRET,VCO,GRE(21),VC(21),TAC
      COMMON LAND(21),MAN(21)
      COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),NCLS(21)
      COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
      COMMON TPE(21),TIN,TEN,EXEM
      COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
      COMMON TAS,TA,PA
      COMMON TAXCR(21)
      IF(TIN.LE.0.) GO TO 150
      IF(TIN.LT.QA.AND.TIN.GT.0.) GO TO 151
      IF(TIN.LT.PB.AND.TIN.GE.QA) GO TO 152
      IF(TIN.LT.PC.AND.TIN.GE.PB) GO TO 153
      IF(TIN.LT.PD.AND.TIN.GE.PC) GO TO 154
      IF(TIN.LT.PE.AND.TIN.GE.PD) GO TO 155
      IF(TIN.LT.PF.AND.TIN.GE.PE) GO TO 156
      IF(TIN.LT.PG.AND.TIN.GE.PF) GO TO 157
      IF(TIN.LT.PH.AND.TIN.GE.PG) GO TO 158
      IF(TIN.LT.PI.AND.TIN.GE.PH) GO TO 159
      IF(TIN.LT.PJ.AND.TIN.GE.PI) GO TO 160
      IF(TIN.GE.PJ) GO TO 161
  150 TA = 0.0
      GO TO 77
  151 TA = TIN * .09
      GO TO 77
  152 TA = 1234. + (.19 * (TIN - QA))
      GO TO 77
  153 TA = 2113. + (.22 * (TIN - PB))
      GO TO 77
  154 TA = 2937. + (.25 * (TIN - PC))
      GO TO 77
  155 TA = 4037. + (.29 * (TIN - PD))
      GO TO 77
  156 TA = 5574. + (.33 * (TIN - PE))
      GO TO 77
  157 TA = 7323. + (.39 * (TIN - PF))
      GO TO 77
  158 TA = 11457. + (.44 * (TIN - PG))
      GO TO 77
  159 TA = 17705. + (.49 * (TIN - PH))
      GO TO 77
  160 TA = 30249. +(.50 * (TIN - PI))
      GO TO 77
  161 TA = 42149. + (.50 * (TIN - PJ))
      GO TO 77
   77 IF(TEN.LE.0.) GO TO 119
      IF(TEN.LT.QA.AND.TEN.GT.0.) GO TO 120
      IF(TEN.LT.PB.AND.TEN.GE.QA) GO TO 121
      IF(TEN.LT.PC.AND.TEN.GE.PB) GO TO 122
      IF(TEN.LT.PD.AND.TEN.GE.PC) GO TO 123
      IF(TEN.LT.PE.AND.TEN.GE.PD) GO TO 124
      IF(TEN.LT.PF.AND.TEN.GE.PE) GO TO 125
      IF(TEN.LT.PG.AND.TEN.GE.PF) GO TO 126
      IF(TEN.LT.PH.AND.TEN.GE.PG) GO TO 127
      IF(TEN.LT.PI.AND.TEN.GE.PH) GO TO 128
      IF(TEN.LT.PJ.AND.TEN.GE.PI) GO TO 129
      IF(TEN.GE.PJ) GO TO 130
  119 PA = 0.0
      RETURN
  120 PA = TEN * .09
      RETURN
```

TABLE XXXV (Continued)

```
      121 PA = 1234. + (.19 * (TEN - QA))
          RETURN
      122 PA = 2013. + (.22 * (TEN - PB))
          RETURN
      123 PA = 2937. + (.25 * (TEN - PC))
          RETURN
      124 PA = 4037. + (.29 * (TEN - PD))
          RETURN
      125 PA = 5574. + (.33 * (TEN - PE))
          RETURN
      126 PA = 7323. + (.39 * (TEN - PF))
          RETURN
      127 PA = 11457. + (.44 * (TEN - PG))
          RETURN
      128 PA = 17705. + (.49 * (TEN - PH))
          RETURN
      129 PA = 30249. +(.50 * (TEN - PI))
          RETURN
      130 PA = 42149. + (.50 * (TEN - PJ))
          RETURN
          END
C         ***************************************************************

          SUBROUTINE TAX3
          COMMON NLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
          COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,OLIST
          COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
          COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
          COMMON GRET,VCO,GRE(21),VC(21),TAC
          COMMON LAND(21),MAN(21)
          COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),MOLD(21)
          COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
          COMMON TPE(21),TIN,TEN,EXEM
          COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
          COMMON TAS,TA,PA
          COMMON TAXCR(21)
          IF(TIN.LE.0.) GO TO 250
          IF(TIN.LT.QA.AND.TIN.GT.0.) GO TO 251
          IF(TIN.LT.PB.AND.TIN.GE.QA) GO TO 252
          IF(TIN.LT.PC.AND.TIN.GE.PB) GO TO 253
          IF(TIN.LT.PD.AND.TIN.GE.PC) GO TO 254
          IF(TIN.LT.PE.AND.TIN.GE.PD) GO TO 255
          IF(TIN.LT.PF.AND.TIN.GE.PE) GO TO 256
          IF(TIN.LT.PG.AND.TIN.GE.PF) GO TO 257
          IF(TIN.LT.PH.AND.TIN.GE.PG) GO TO 258
          IF(TIN.LT.PI.AND.TIN.GE.PH) GO TO 259
          IF(TIN.LT.PJ.AND.TIN.GE.PI) GO TO 260
          IF(TIN.GT.PJ) GO TO 261
      250 TA = 0.0
          GO TO 37
      251 TA = TIN * .085
          GO TO 37
      252 TA = 1149. + (.17 * (TIN - QA))
          GO TO 37
      253 TA = 1346. + (.19 * (TIN - PB))
          GO TO 37
      254 TA = 2644. + (.23 * (TIN - PC))
          GO TO 37
      255 TA = 3656. + (.26 * (TIN - PD))
          GO TO 37
```

TABLE XXXV (Continued)

```
  256 TA = 5034. + (.30 * (TIN - PE))
      GO TO 87
  257 TA = 6624. + (.35 * (TIN - PF))
      GO TO 87
  258 TA = 10334. + (.40 * (TIN - PG))
      GO TO 87
  259 TA = 15014. + (.44 * (TIN - PH))
      GO TO 87
  260 TA = 27278. + (.48 * (TIN - PI))
      GO TO 87
  261 TA = 38702. + (.50 * (TIN - PJ))
      GO TO 87
   87 IF(TEN.LE.0.) GO TO 219
      IF(TEN.LT.QA.AND.TEN.GT.0.) GO TO 220
      IF(TEN.LT.PB.AND.TEN.GE.QA) GO TO 221
      IF(TEN.LT.PC.AND.TEN.GE.PB) GO TO 222
      IF(TEN.LT.PD.AND.TEN.GE.PC) GO TO 223
      IF(TEN.LT.PE.AND.TEN.GE.PD) GO TO 224
      IF(TEN.LT.PF.AND.TEN.GE.PE) GO TO 225
      IF(TEN.LT.PG.AND.TEN.GE.PF) GO TO 226
      IF(TEN.LT.PH.AND.TEN.GE.PG) GO TO 227
      IF(TEN.LT.PI.AND.TEN.GE.PH) GO TO 228
      IF(TEN.LT.PJ.AND.TEN.GE.PI) GO TO 229
      IF(TEN.GE.PJ) GO TO 230
  219 PA = 0.0
      RETURN
  220 PA = TEN * .085
      RETURN
  221 PA = 1149. + (.17 * (TEN - QA))
      RETURN
  222 PA = 1846. + (.19 * (TEN - PB))
      RETURN
  223 PA = 2644. + (.23 * (TEN - PC))
      RETURN
  224 PA = 3656. + (.26 * (TEN - PD))
      RETURN
  225 PA = 5034. + (.30 * (TEN - PE))
      RETURN
  226 PA = 6624. + (.35 * (TEN - PF))
      RETURN
  227 PA = 10334. + (.40 * (TEN - PG))
      RETURN
  228 PA = 15014. + (.44 * (TEN - PH))
      RETURN
  229 PA = 27278. + (.48 * (TEN - PI))
      RETURN
  230 PA = 38702. + (.50 * (TEN - PJ))
      RETURN
      END
C     ******************************************************************

      SUBROUTINE TAX4
      COMMON NLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
      COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON IEQ,PRICE(21),TCOST(21),TER(21),SAL(21)
      COMMON IA,N,M1,M2,IER,I,J,K,L,Z,S
      COMMON GRET,VCO,GRE(21),VC(21),TAC
      COMMON LAND(21),MAN(21)
      COMMON TAP(21),TSP(21),TWP(21),TRAC(21),TAND(21),HOLD(21)
      COMMON FIEC(21),SPRIN(21),RILL(21),RCUL(21),SPRA(21)
```

TABLE XXXV (Continued)

```
      COMMON TPE(21),TIN,TEN,EXEM
      COMMON QA,PB,PC,PD,PE,PF,PG,PH,PI,PJ
      COMMON TAS,TA,PA
      COMMON TAXCR(21)
      IF(TIN.LE.0.) GO TO 350
      IF(TIN.LT.QA.AND.TIN.GT.0.) GO TO 351
      IF(TIN.LT.PB.AND.TIN.GE.QA) GO TO 352
      IF(TIN.LT.PC.AND.TIN.GE.PB) GO TO 353
      IF(TIN.LT.PD.AND.TIN.GE.PC) GO TO 354
      IF(TIN.LT.PE.AND.TIN.GE.PD) GO TO 355
      IF(TIN.LT.PF.AND.TIN.GE.PE) GO TO 356
      IF(TIN.LT.PG.AND.TIN.GE.PF) GO TO 357
      IF(TIN.LT.PH.AND.TIN.GE.PG) GO TO 358
      IF(TIN.LT.PI.AND.TIN.GE.PH) GO TO 359
      IF(TIN.LT.PJ.AND.TIN.GE.PI) GO TO 360
      IF(TIN.GE.PJ) GO TO 361
  350 TA = 0.0
      GO TO 97
  351 TA = TIN * .08
      GO TO 97
  352 TA = 1035. + (.16 * (TIN - QA))
      GO TO 97
  353 TA = 1741. + (.18 * (TIN - PB))
      GO TO 97
  354 TA = 2497. + (.22 * (TIN - PC))
      GO TO 97
  355 TA = 3465. + (.25 * (TIN - PD))
      GO TO 97
  356 TA = 4790. + (.28 * (TIN - PE))
      GO TO 97
  357 TA = 6274. + (.33 * (TIN - PF))
      GO TO 97
  358 TA = 9772. + (.38 * (TIN - PG))
      GO TO 97
  359 TA = 15168. + (.42 * (TIN - PH))
      GO TO 97
  360 TA = 25920. + (.45 * (TIN - PI))
      GO TO 97
  361 TA = 36630. + (.49 * (TIN - PJ))
      GO TO 97
   97 IF(TEN.LE.0.) GO TO 319
      IF(TEN.LT.QA.AND.TEN.GT.0.) GO TO 320
      IF(TEN.LT.PB.AND.TEN.GE.QA) GO TO 321
      IF(TEN.LT.PC.AND.TEN.GE.PB) GO TO 322
      IF(TEN.LT.PD.AND.TEN.GE.PC) GO TO 323
      IF(TEN.LT.PE.AND.TEN.GE.PD) GO TO 324
      IF(TEN.LT.PF.AND.TEN.GE.PE) GO TO 325
      IF(TEN.LT.PG.AND.TEN.GE.PF) GO TO 326
      IF(TEN.LT.PH.AND.TEN.GE.PG) GO TO 327
      IF(TEN.LT.PI.AND.TEN.GE.PH) GO TO 328
      IF(TEN.LT.PJ.AND.TEN.GE.PI) GO TO 329
      IF(TEN.GE.PJ) GO TO 330
  319 PA = 0.0
      RETURN
  320 PA = TEN * .08
      RETURN
  321 PA = 1035. + (.16 * (TEN - QA))
      RETURN
  322 PA = 1741. + (.18 * (TEN - PB))
      RETURN
```

TABLE XXXV (Continued)

```
 323 PA = 2497. + (.22 * (TEN - PC))
     RETURN
 324 PA = 3465. + (.25 * (TEN - PD))
     RETURN
 325 PA = 4790. + (.28 * (TEN - PE))
     RETURN
 326 PA = 6274. + (.33 * (TEN - PF))
     RETURN
 327 PA = 9772. + (.38 * (TEN - PG))
     RETURN
 328 PA = 15168. + (.42 * (TEN - PH))
     RETURN
 329 PA = 25920. + (.45 * (TEN - PI))
     RETURN
 330 PA = 36630. + (.49 * (TEN - PJ))
     RETURN
     END

$ENTRY
```

VITA

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Candidate for the Degree of

Master of Science

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